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THOMAS JEFFERSON
HIS INTEREST IN PLANT LIFE AS REVEALED IN HIS WRITINGS*—I

EDMUND H. FULLING

The amazing versatility of Thomas Jefferson has been much extolled by his biographers, and numerous have been the eulogies inspired by it. As a political philosopher of the early American republic, Jefferson will always stand preeminent, and to him in the future there will be attributed, as in years gone by, many a political concept that seeks the authority of great men become venerable through their wisdom and the passage of time. In other fields of intellectual endeavor he was scarcely less astute, and in his grasp of great principles and simultaneous devotion to details, he displayed an "exquisite mind, which was both telescopic and microscopic in its range and operations" (7).

It is because of this amazing versatility, encompassing many fields of science, particularly an enduring interest in plant life, that another contribution is here offered to the already voluminous literature upon the life of this great statesman. Most previous biographical sketches of Jefferson have at least recognized his life-long concern with agriculture, and a few have emphasized his broader interests in plants. Among the latter are accounts of his relation to botany (27), of his gardening activities (4, 28) and, most recently, of his relation to all sciences of his time, including agriculture, botany and horticulture (6).[1] Despite these excellent treatises there is in his writings evidence of still greater interest in the vegetable world than has so far been recognized, other than by cursory allusion. It is the purpose of the present study to unite, in some measure, these hitherto unemphasized discourses of Jefferson with those which have already been revealed, and thus to provide in botanical literature a more inclusive account of Jefferson's role as agriculturist, botanist, and gardener.

Considered thus in their entirety, Jefferson's writings on plants give us not only a better understanding of the man himself but also an assemblage of data possessing historical value from purely agricultural and botanical standpoints. This is particularly true with respect to plants of economic value. Jefferson's interest in all branches of science was primarily utilitarian, and the introduction of useful plants as well as improved agricul-

* Prepared in partial fulfillment of an Act of Congress to commemorate the two hundredth anniversary of the birth of Jefferson.

[1] This scholarly article was published as a "prereprint" shortly after the present study was begun. In a large measure, it considers phases of Jefferson's interests previously recorded only in his own writings, and unavoidably mentioned again and even cited in the present account.

tural practices were constant concerns of his. Nevertheless, the present contribution is essentially biographical; its principal objective is to reveal something of the personality of a great man as his phenomenal mentality penetrated into nearly every branch of human knowledge.

To that end, impersonal paraphrasing of his writings is deliberately avoided; instead, abundant quotations from his works are cited. It is only through such quotations and not by the words of another author in feeble attempts to describe them that a reader may secure his own realistic impressions of one unknown to him personally, and not merely the impressions of a eulogistic biographer. Furthermore, there are so many interesting details in the writings of a man like Jefferson, that any one attempting to embody them accurately in a new rendition inevitably must resort to citations. Ample evidence is at hand that others, too, have come to this conclusion, for there have already been published various compilations of choice selections from his writings on a variety of topics, including agriculture, a comprehensive two-volume assemblage of which will appear shortly under Government imprint.

Jefferson was a phenomenally prolific writer, not of "books" or of articles for publication—he strictly adhered to a policy of never writing for the "press"—but of letters, 40,000 pieces of which in 236 volumes repose today among his manuscripts in the Library of Congress, with an additional 10,000 in 67 volumes in the library of the Massachusetts Historical Society (2). Other papers are in the custody of the Huntington Library, San Merino, California; the Pennsylvania Historical Society; the Missouri Historical Society; and the University of Virginia. Some 325 letters of this voluminous correspondence deal with agricultural matters. When it is borne in mind that this prodigious personal correspondence was carried on in longhand and that Jefferson preserved a duplicate of most of it, made by means of moistened paper or an ingenious polygraph of his own design and construction, one marvels, to say the least, at the astounding industry of the man.

A major portion of this correspondence has been published in three large works, one of nine (11), another of ten (12) and the third of 20 volumes (13), none of which has been regarded as wholly satisfactory, either quantitatively or qualitatively. To remedy this situation there is now in preparation a definitive edition of the papers of Thomas Jefferson, to include not only all his available writings but also all preserved letters written to him, and to comprise some 50 volumes. It is under the editorship of Julian Boyd, historian and librarian of Princeton University, and will be published by the Princeton University Press. Some idea of the enormous variety of topics which this monumental work will cover may be gained from the cyclopedia of 1900 founded upon the ten-volume edition; that compendium assembles

quotations from Jefferson's writings under 9,228 headings (16). One wonders, indeed, what the index to the contemplated 50 volumes will offer by way of subject matter. The present paper is based almost wholly on the 20-volume edition, whence almost all the quotations given have been extracted.

In addition to the many references to plant life in his correspondence, Jefferson left for posterity among his meticulously kept account books, two detailed records which also are of great interest to us, his "Farm Book" and his "Garden Book." The former was begun in 1774 and continued until 1822; the latter, started in 1766 and continued, except during his absence, until 1824. Both of them have hitherto been only in manuscript form. This year, however, the American Philosophical Society, of which Jefferson at one time was president, has published an annotated edition of the "Garden Book" under the editorship of Professor E. M. Betts of the University of Virginia, who has been instrumental in the restoration of Jefferson's gardens at Monticello; and the "Farm Book" may be included in the contemplated Government edition of all Jefferson's agricultural writings, already referred to.

I. AGRICULTURE

INTRODUCTION

Thomas Jefferson was a member of the landed gentry in colonial Virginia, in the days when young America was still primarily an agricultural country. By inheritance of more than 2,000 acres from his father and by subsequent purchases of his own, he became the proprietor, by 1794 and at the age of 51, of 10,647 acres. This area, according to his "Farm Book," consisted of 15 parcels of land, several of which made up his Albemarle estate of 5,591⅜ acres wherein was included his now famous home of Monticello, on a mountaintop overlooking and about three miles from the town of Charlottesville. Less than 1,200 acres of this Albemarle holding was ever cleared of trees and put under cultivation, and on another parcel, of more than 4,000 acres, known as Poplar Forest, only about 800 acres came under the axe. One of the smallest parcels, of only 157 acres, was in wilderness and contained what today is one of the "shrines" of America and at which Jefferson long hoped to build a retreat for himself—the Natural Bridge of Virginia.

That Jefferson's heart and soul were always in Monticello and the surrounding country and that his 40 years[2] in statecraft were but an interlude in his preferred preoccupations with his farms and garden, is attested by many references in his correspondence to the day when he might return to

[2] From his election to the House of Burgesses of the Colony of Virginia in 1769 to his retirement from the Presidency in 1809.

them. He began construction on Monticello in 1770, managed his farms for 14 years, and in 1784, after the turmoil of the Revolution, was sent to Europe with Franklin and Adams to negotiate commercial treaties with European powers. The next year he succeeded Franklin as American representative to France, and did not return to America until 1789. During the intervening years, while residing in Paris, he accommodated himself to the pomp and circumstance of a regal court, serving his country but ever thinking of his Albemarle estate. Four years before the termination of his tenure in that office he confessed to a French acquaintance:

"I am savage enough to prefer the woods, the wilds, and the independence of Monticello, to all the brilliant pleasures of this gay Capital. I shall, therefore, rejoin myself to my native country, with new attachments, and with exaggerated esteem for its advantages; for though there is less wealth there, there is more freedom, more ease, and less misery"[3]

Upon his return to America, four years later, Jefferson entered Washington's cabinet as the first American Secretary of State but retired from that position the last day of 1793. In 1794 he returned to Monticello and gave vent to his feelings when he wrote to Washington:

"I return to farming with an ardor which I scarcely knew in my youth, and which has got the better entirely of my love of study. Instead of writing ten or twelve letters a day, which I have been in the habit of doing as a thing in course, I put off answering my letters now, farmer-like, till a rainy day, and then find them sometimes postponed by other necessary occupations."[4]

The next year, in writing to James Madison about his broken down health of the last eight months, he wrote on

"above all things, the delights I feel in the society of my family, and in the agricultural pursuits in which I am so eagerly engaged."[5]

It was not many years, however, before his public services were again demanded by his country, this time as President of the United States. That his interest in agricultural matters never slackened during the eight years in that office is attested in several ways, perhaps the most interesting of which is his faithful formulation during all those years of a chart which showed the average earliest and latest dates of appearance in the Washington market of 36 varieties of vegetables. From this table we learn that Washingtonians of those days were supplied at various times during the year with

artichokes	broccoli	cauliflower
asparagus	cabbage	celery
beets	carrots	corn

[3] Letter to Baron Geismer, September 6, 1785 (13, V, *127*).
[4] Letter to George Washington, April 25, 1794 (13, IX, *283*).
[5] Letter to James Madison, April 27, 1795 (13, IX, *301*).

cress	mushrooms	sorrel
cucumbers	parsley	spinach
currants	parsnips	sprouts
eggplant	peas	squash
endive	potatoes	strawberries
grapes	radishes	tomatoes
lettuce	raspberries	turnips
lima beans	salsifia	watermelon
melons	snaps	windsor beans

Two of Jefferson's biographers have reproduced this chart in their works (6, 24), and one of them, especially impressed by his devotion to details and ability to detach himself from the weighty matters of State, was induced to comment (24): "To think of a leader of a great civil revolution—the founder of a new party and creed—the statesman engaged in the pressing cares of a nation—watching with a green-grocer's assiduity, and recording with more than a green-grocer's precision, the first and last appearance of radishes, squashes, cabbages, and cauliflowers in the market—suggests a curious train of reflections."

It would be unfortunate, indeed, were Jefferson's formulation of that chart to do no more than "suggest a curious train of reflections"; it should serve, rather, as a precept to be emulated of unswerving interest despite the more urgent cares, faithfully discharged, which interrupted his devotion to a chosen avocation.

In 1808, when about to retire from those cares, we again find Jefferson longing for Monticello when he wrote to Chancellor Livingston, the eminent jurist and statesman, thanking him for certain volumes of Agricultural Proceedings and mentioning receipt of other proceedings from the Agricultural Society of Paris:

"Writings on this subject are peculiarly pleasing to me, for, as they tell us, we are sprung from the earth, so to that we naturally return. It is now among my most fervant longings to be on my farm, which, with a garden and fruitery, will constitute my principal occupation in retirement."[6]

And after consummation of this longing he wrote to an old classmate:

"I have withdrawn myself from all political intermeddlings, to indulge the evening of my life with what have been the passions of every portion of it, books, science, my farms, my family and friends."[7]

Agricultural pursuits were thus not merely incidental events in Jefferson's life; together with other phases of natural science, physics, chemistry, mechanics, and what not else, they ranked foremost in his thoughts, and earned for him the rather substantial income for those days of about $2,000 per year. In company with Washington and others, he was one of the most

[6] Letter to R. R. Livingston, January 3, 1808 (13, XI, *411*).

[7] Letter to James Maury, April 25, 1812 (13, XIII, *144*).

progressive farmers of his time, so far as seeking improvements in techniques and crops was concerned, though not the most successful in yields obtained. To his farming practices he applied, with whatever modifications seemed necessary, the teachings of recognized agricultural authorities, and toward this end, we are told, he had in his extensive library, 78 volumes upon agriculture, 48 of which were in English, 24 in French, five in Italian and one in Latin (6).[8]

The details of these activities, minutely recorded in his "Farm Book," are obviously beyond consideration in a paper of the present size. Certain generalities, however, must not be overlooked in any treatment of the subject, and these will now be noted.

AGRICULTURAL ACTIVITIES AT MONTICELLO

Tobacco, Corn, and Wheat. For a great many years after the founding of Virginia by the first permanent English settlement at Jamestown in 1607, tobacco was the most important staple crop of the colonists, even the principal medium of currency at one period, and its culture was undertaken by practically every landowner, large and small. It long constituted the most valuable export of all the colonies, and from 1744 to 1776 the amounts shipped abroad averaged about 40,000,000 pounds per year. Jefferson, as a plantation owner, contributed to this production in the early days of Monticello, where at one time he was called master by 154 slaves. Tobacco was an important source of revenue to those who raised it, and on one occasion, at least, Jefferson expected to realize £50 sterling per hogshead on his produce.[9]

The usual routine of growing it in those days was to remove the forest from virgin land, to plant the weed for five successive years, and then to let the land lie fallow for a season or more, followed by a repetition of this sequence until the crop raised no longer was remunerative. Rotation of crops was generally not practiced, and manuring the land was out of the question to restore its pristine fertility after so wantonly destroying it by this barbaric spoliation; it was cheaper to buy new land, to clear it and to extend the ravaging husbandry.

There were a few thoughtful farmers, however, among them Washington and Jefferson, who condemned this exploitation and were quick to recognize that the heyday of Virginia tobacco was gradually fading after the three-quarter mark of the century. The market price was falling, cheaper

[8] Though the inclusion of these volumes in Jefferson's library indicates his interest in plant life as well as do other phases of his activities, they will not be enumerated or further discussed here because they are not among his writings. For an interesting commentary upon them, the reader is referred to Dr. Brown's article (6). It must be mentioned, however, that Jefferson's library, purchased by Congress in 1815, became the nucleus of the present Library of Congress after the original was burned.

[9] Letter to Thomas Adams, February 20, 1771 (13, IV, *229*).

lands had to be sought elsewhere, and long before he returned to Monticello in 1794 Jefferson abandoned cultivation of the exhausting weed on his Albemarle estate. In his "Notes on the state of Virginia," published ten years earlier in Paris, he remarked:

"In the year 1758 we exported seventy thousand hogsheads of tobacco, which was the greatest quantity ever produced in this country in one year. But its culture was fast declining at the commencement of this war[10] and that of wheat taken its place; and it must continue to decline on the return of peace. I suspect that the change in the temperature of our climate has become sensible to that plant, which to be good, requires an extraordinary degree of heat. But it requires still more indispensably an uncommon fertility of soil; and the price which it commands at market will not enable the planter to produce this by manure. Was the supply still to depend on Virginia and Maryland alone as its culture becomes more difficult, the price would rise so as to enable the planter to surmount those difficulties and to live. But the western country on the Mississippi, and the midlands of Georgia, having fresh and fertile lands in abundance, and a hotter sun, will be able to undersell these two States and will oblige them to abandon the raising of tobacco altogether. And a happy obligation for them it will be. It is a culture productive of infinite wretchedness. Those employed in it are in a continual state of exertion beyond the power of nature to support. Little food of any kind is raised by them; so that the men and animals on these farms are badly fed, and the earth is rapidly impoverished."[11]

In lieu of tobacco Jefferson advocated that

"The cultivation of wheat is the reverse in every circumstance. Besides clothing the earth with herbage and preserving its fertility, it feeds the laborers plentifully, requires from them only a moderate toil except in the season of harvest, raises great numbers of animals for food and service, and diffuses plenty and happiness among the whole. We find it easier to make an hundred bushels of wheat than a thousand weight of tobacco and they are worth more when made."[11]

This substitution of crops did not, however, preserve the fertility of his lands, for during his ten years' absence from Monticello his overseers practiced a rotation which exhausted the soil probably more though less rapidly than did tobacco. They sowed wheat and maize in alternate years in the virgin soil of newly cleared land between the stumps of felled trees, and repeated this rotation so long as they could get five bushels of wheat or ten bushels of corn per acre. This system was followed probably under the influence of John Taylor, an exceptionally good farmer of Caroline County, Virginia, "whose bountiful crops bore witness to the merits of his teachings." Taylor argued strongly in favor of maize as the alternate crop in preference to the English dependence on turnips, peas and potatoes. After the yield of wheat or Indian corn no longer was remunerative, the land was aban-

[10] War between France and England.

[11] (13, II, *231*).

doned and new areas cleared for similar exploitation; all of which offered little improvement over the previous era of tobacco culture.

Jefferson was Secretary of State at this time, keeping an eye on his declining farms as best he could, and attempting to remedy matters by engaging proper overseers. Two years before returning to Monticello he hired one Samuel Biddle as superintendent, who was willing to undertake the job for $120 per year, wages which were a good deal higher than Jefferson expected to pay. In his instructions to Biddle, Jefferson furnished us some particulars when he wrote to him that

"The farm is of about five or six hundred acres of cleared land, very hilly, originally as rich as any highlands in the world but much worried by Indian corn & tobacco. It is still however very strong, & remarkably friendly to wheat & rye. These will be my first object. Next will be grasses, . . . & the introduction of potatoes for the use of the farm, instead of Indian corn, in as great a degree as possible. . . . I have long banished tobacco, & wish to do the same by Indian corn in a great degree."[12]

At the same time Jefferson had an area of 2,000 acres which he wanted to rent in parcels of not less than 200 acres at 25¢ per acre, but always with restrictions against growing too much Indian corn. On this point he wrote in his "Farm Book," under the heading "Tenants":

"Tie them up to some rotation of crops which shall include ameliorating years to counterbalance at least the exhausting ones,"

and to Mr. Freeman, in charge of Monticello, he wrote with respect to one lessor:

"I understand this tenant has tended the same ground in corn both the years he has lived on it. He must therefore go off unless he will put the whole of it into wheat now, or oats in the spring. If he does not, we must put it in oats in the spring . . ." (24).

President Washington, at this time, was in correspondence with the eminent English agricultural writer, Arthur Young, concerning problems of his own. Jefferson appears to have shared in the exchange of letters, and in commenting to the President upon some of Young's recommendations, he indicates the contemplated changes in agricultural practice which he soon adopted:

"Good husbandry with us consists in abandoning Indian corn and tobacco, tending small grain, some red clover following, and endeavoring to have, while the lands are at rest, a spontaneous cover of white clover. I do not present this as a culture judicious in itself, but as *good* in comparison with what most people there pursue. Mr. Young has never had an opportunity to see how slowly the fertility of the *original soil* is exhausted. With moderate management of it, I can affirm that the James river lowgrounds with the cultivation of small grains, will never be exhausted; because we

[12] Letter to Samuel Biddle, December 12, 1792 (13, XVIII, *189*).

know that under that cultivation we must now and then take them down with Indian corn, or they become, as they were originally, too rich to bring wheat. The highlands, where I live, have been cultivated about sixty years. The culture was tobacco and Indian corn as long as they would bring enough to pay the labor. Then they were turned out. After four or five years rest they would bring good corn again, and in double that time perhaps good tobacco. Then they would be exhausted by a second series of tobacco and corn. Latterly we have begun to cultivate small grain; and excluding Indian corn, and following, such of them as were originally good, soon rise up to fifteen or twenty bushels the acre. . . . I mean in a farm of about 500 acres of cleared land and with a dozen laborers to try the plan of wheat, rye, potatoes, clover, with a mixture of some Indian corn with the potatoes. . . ."[13]

About a year later, in again writing to Washington about the depleted state of his farms, he was induced by further inspection of them to exclaim:

"Ten years' abandonment of them to the ravages of overseers, has brought on them a degree of degradation far beyond what I had expected."[14]

Jefferson's Rotation of Crops as a Final Effort to Restore the Depleted Fertility of His Soil. In a final effort to rescue his land from utter destruction as a result of incompetent management during his absence abroad, Jefferson adopted a new plan of crop rotation in 1794 when he returned to Monticello. He divided the 1,120 acres under cultivation into four farms of 280 acres each, and each farm into seven fields of 40 acres, marking the boundaries by rows of peach trees, of which he set out 1,151 that first year. The seven fields indicated the basic nature of the new system, a seven-year rotation, and each farm, under its own overseer, was cultivated by four negroes, four negresses, four horses and four oxen. The precise sequence of crops which Jefferson followed in this new scheme apparently varied somewhat, for the many references to it in his correspondence indicate changes from year to year. As related to John Taylor, the agricultural authority of the time, it was as follows: first year—wheat, followed that same year by turnips to be fed to the sheep; second year—corn and potatoes in alternate rows, followed in autumn by winter vetch to be used in the spring as fodder, if so wanted, or to be turned in; third year—peas or potatoes, or both, according to the quality of the field; fourth year—rye or wheat with clover; fifth and sixth years—clover, turned in the autumn of the latter and followed by vetch; seventh year—the vetch plowed under in the spring, buckwheat sown and turned in later, followed by autumn wheat to begin the cycle again.

Jefferson's agricultural correspondence contains abundant references to this system of rotation, to its modifications, its merits and its results. It is in that same letter to Taylor, however, that we find perhaps the best expression of his concern with it and of his understanding in the matter:

[13] Letter to George Washington, June 28, 1793 (13, IX, *139*).
[14] Letter to George Washington, May 14, 1794 (13, IX, *286*).

"And though I observe your strictures on rotations of crops, yet it appears that in this I differ from you only in words. You keep half your lands in culture, the other half at nurse; so I propose to do. Your scheme indeed requires only four years and mine six; but the proportion of labor and rest is the same. My years of rest, however, are employed, two of them in producing clover, yours in volunteer herbage. But I still understand it to be your opinion that clover is best where lands will produce them. Indeed I think that the important improvement for which the world is indebted to Young is the substitution of clover crops instead of unproductive fallows; and the demonstration that lands are more enriched by clover than by volunteer herbage or fallows; and the clover crops are highly valuable. That our red lands which are still in tolerable heart will produce fine clover I know from the experience of the last year; and indeed that of my neighbors had established the fact. And from observations on accidental plants in the fields which have been considerably harrassed with corn, I believe that even these will produce clover fit for soiling of animals green. I think, therefore, I can count on the success of that improver. My third year of rest will be devoted to cowpenning, and to a trial of the buckwheat dressing. A further progress in surveying my open arable lands has shewn me that I can have seven fields in each of my farms where I expected only six; consequently that I can add more to the portion of rest and ameliorating crops. I have doubted on a question on which I am sure you can advise me well, whether I had better give this newly acquired year as an addition to the continuance of my clover, or throw it with some improving crop between two of my crops of grain, as for instance between my corn and rye. I strongly incline to the latter, because I am not satisfied that one cleansing crop in seven years will be sufficient; and indeed I think it important to separate my exhausting crops by alternations of ameliorators. With this view I think to try an experiment of what Judge Parker informs me he practices. That is, to turn in my wheat stubble the instant the grain is off, and sow turnips to be fed out by the sheep. But whether this will answer in our fields which are harrassed, I do not know. We have been in the habit of sowing only our freshest lands in turnips, hence a presumption that wearied lands will not bring them. But Young's making turnips to be fed on by sheep the basis of his improvement of poor lands, affords evidence that though they may not bring great crops, they will bring them in a sufficient degree to improve the lands. I will try that experiment, however, this year, as well as the one of buckwheat. I also attended to another improver mentioned by you, the winter vetch, and have taken measures to get the seed of it from England, as also of the Siberian vetch which Millar greatly commends, and being a biennial might perhaps take the place of clover in lands which do not suit that. The winter vetch I suspect may be advantageously thrown in between crops, as it gives a choice to use it as green feed in the spring if fodder be run short, or to turn it in as green-dressing.

I am for throwing the whole force of my husbandry on the wheat-field, because it is the only one which is to go to market to produce money. Perhaps the clover may bring in something in the form of stock. The other fields are merely for the consumption of the farm. Melilot, mentioned by you, I never heard of. The horse bean I tried this last year. It turned out nothing. The President has tried it without success. An old English farmer of the name of

Spuryear, settled in Delaware, has tried it there with good success; but he told me it would not do without being well shaded, and I think he planted it among his corn for that reason. But he acknowledged our pea was as good an ameliorator and a more valuable pulse, as being food for man as well as horse. The succory is what Young calls Chicoria Intubus. He sent some seed to the President, who gave me some, and I gave it to my neighbors to keep up till I should come home. One of them has cultivated it with great success, is very fond of it, and gave me some seed which I sowed last spring. Though the summer was favorable it came on slowly at first, but by autumn became large and strong. It did not seed that year, but will the next, and you shall be furnished with seed. I suspect it requires rich ground, and then produces a heavy crop for green feed for horses and cattle. I had poor success with my potatoes last year, not having made more than 60 or 70 bushels to the acre. But my neighbors having made good crops, I am not disheartened. The first step towards the recovery of our lands is to find substitutes for corn and bacon. I count on potatoes, clover, and sheep. The two former to feed every animal on the farm except my negroes, and the latter to feed them, diversified with rations of salted fish and molasses, both of them wholesome, agreeable, and cheap articles of food."

After discussing the possibilities of a "movable airy cow house, to be set up in the middle of the field which is to be dunged," Jefferson continues:

". . . observe that the turnips and two dressings of vetch do not cost a single ploughing. The turning the wheat-stubble for the turnips is the fallow for the corn of the succeeding year. The first sowing of vetches is on the corn (as is now practised for wheat), and the turning it in is the flush-ploughing for the crop of potatoes and peas. The second sowing of the vetch is on the wheat fallow, and the turning it in is the ploughing necessary for sowing the buckwheat. These three ameliorations, then, will cost but a single harrowing each. On the subject of the drilled husbandry, I think experience has established its preference for some plants, as the turnip, pea, bean, cabbage, corn, etc., and that of the broadcast for other plants as all the bread grains and grasses, except perhaps lucerne and Saint foin in soils and climates very productive of weeds. In dry soils and climates the broadcast is better for lucerne and Saint foin, as all the south of France can testify."[15]

While Jefferson was thus a pioneer in adopting to America the new agricultural practices being developed in England, and especially in advocating elaborate rotation of crops and use of legumes, he was by no means either the only one or the first to do so. Two years earlier, Washington had also adopted a seven-year rotation, believing with Jefferson that potatoes improved the soil. It was the use of legumes, however, which seems to have been paramount in Jefferson's mind as a means of improving his soil, and several references to the plants in his letters reveal his satisfaction with them. From a letter to James Madison, for instance, we learn that in 1794 he sowed about 40 acres to them, 120 acres the next year, and planned to sow 160–200 acres yearly thereafter.[16] On another occasion he claimed never to have seen finer

[15] Letter to John Taylor, December 29, 1794 (13, XVIII, *192*).
[16] Letter to James Madison, April 27, 1795 (13, IX, *301*).

clover than in some of his fields which had never been previously manured, and on which his rotation at the time was triennial: one year of wheat and two of clover in the strongest fields, or two of peas in the weaker, with maize and potatoes after every other rotation, i.e., once in seven years.[17]

Additional light is shed upon Jefferson's legume husbandry by a letter to Washington in which he first defended himself against the attempt of someone who "thought it worth his while to try to sow tares between you and me, by representing me as still engaged in the bustle of politics, and in turbulence and intrigue against the government." Jefferson had laid down as a rule for himself never to write a word for the public papers, and he claimed in this letter never to have departed therefrom in a single instance. It appears, however, that something did become public in a publication of the time and attributed to him, which he very much resented. Without naming the person, he suspected someone who had possessed all his and Washington's confidence, but in the copy of the letter which he retained, there was written in the margin, apparently at a later date, the name "General H. Lee." He then continued:

"But enough of this miserable tergiversator, who ought indeed either to have been of more truth, or less trusted by his country.

I put away this disgusting dish of old fragments, and talk to you of my peas and clover. As to the latter article, I have great encouragement from the friendly nature of our soil. I think I have had, both the last and present year, as good clover from common grounds, which had several crops of wheat and corn without ever having been manured, as I ever saw on the lots around Philadelphia. I verily believe that a yield of thirty-four acres . . . has given me a ton to the acre at its first cutting this spring. The stalks extended, measured three and a half feet long very commonly. Another field, a year older, and which yielded as well the last year, has sensibly fallen off this year. My exhausted fields bring a clover not high enough for hay, but I hope to make seed from it. Such as these, however, I shall hereafter put into peas in the broadcast, proposing that one of my sowings of wheat shall be after two years of clover, and the other after two years of peas. I am trying the white boiling pea of Europe (the Albany pea) this year, till I can get the hog pea of England, which is the most productive of all. But the true winter vetch is what we want extremely."[18]

From England and Italy Jefferson received seed of winter vetch and all the good kinds of field pea grown in the former country. While he expected much from them and promised to send some to Taylor, should they succeed with him, he counted a good deal more, he wrote, on the southern cow-pea of the United States.[19] Six months later he had occasion to thank some one for a box of seed, apparently from abroad, and commented that the peas and vetch contained in the consignment were most acceptable. They apparently

[17] Anonymous letter, March 23, 1798 (13, X, *11*).
[18] Letter to George Washington, June 19, 1796 (13, IX, *339*).
[19] Letter to John Taylor, October 8, 1797 (13, XVIII, *201*).

were of a variety already in cultivation in New York, but Jefferson expressed fear that the Virginia soil and sun were not suited to them. He wrote that a recent acquisition of cow-peas had pretty well supplied the place in his husbandry which he had destined for the European field pea. The role of legumes in nitrogen fixation was unknown to Jefferson, and this lack of knowledge accounts for his writing of the cow-pea that it was a

"very productive, excellent food for man and beast, awaits without loss our leisure for gathering, and shades the ground very closely throughout the hottest months of the year. This with the loosening of the soil, I take to be the chief means by which the pea improves the soil."[20]

While Jefferson thus saved his land from complete ruination through uninterrupted cultivation of tobacco and maize, he apparently was always willing to return to them should they ever show signs of becoming profitable in a rising market, and to Taylor he wrote after four years rehabilitation work:

"The high price of tobacco, which is likely to continue for some time, has tempted me to go entirely into that culture, and in the meantime, my farming schemes are in abeyance, and my farming fields at nurse against the time of my resuming them."[21]

Years later, when his lands had presumably recovered some of their former fertility, he wrote in a rather cheerful vein that the vicinity of Charlottesville was excellently adapted to wheat, maize and clover; that garden peas, which were then being planted, came to the table about May 12, strawberries and cherries at about the same time, and asparagus around April 1. Artichoke stood the winter without cover, lettuce and endive with a slight cover. Figs, protected by a little straw, began to ripen in July; otherwise, not until September. The culture of the neighboring people was of wheat for market, of maize, oats, peas and clover for support of the farm. He informed his correspondent that it was regarded as good practice to divide a farm into three fields, putting one in wheat, half a one in maize, the other half in oats or peas, and the third in clover, tending the fields successively in this rotation. The best farmers, such as Mr. Randolph, his son-in-law, got 10 to 20 bushels of wheat per acre; the worst, as himself, 6 to 18.[22]

Other Crops. According to his "Farm Book," in 1812 Jefferson cultivated at Monticello, 32 kinds of vegetables along with 22 crops and 13 varieties of grass. Each of them, very obviously, cannot be discussed in the limits of this article. From his correspondence, however, we learn that at one time he attempted to raise flax but found it so injurious to his lands and of such scanty reward that he discontinued its cultivation. Hemp, on the other hand,

[20] Anonymous letter, March 23, 1798 (13, X, *11*).
[21] Letter to John Taylor, November 26, 1798 (13, X, *63*).
[22] Letter to Jean Batiste Say, March 2, 1815 (13, XIV, *258*).

was abundantly productive and, in his estimation, would grow forever on the same spot. In endeavoring to produce it, however, he found the breaking and beating of it, which was always done by hand, so slow and laborious and so much complained of by his laborers, that he gave it up, and purchased and manufactured cotton for their shirting. He did, however, devise a way of attaching a hemp-break to a threshing machine in an endeavor to revive its cultivation.[23]

Grape vines, too, had their place in Jefferson's program, but by 1822 when some one made inquiry about a certain kind which Jefferson had, so many of the vines had died and others been replaced that he no longer knew one from the other. He did say, however, that the Scuppernon wine of North Carolina, made from a variety of Fox grape, *Vitis vulpina*, from the basin of the Scuppernon river in that State, proved to him that as good wines would some day be made in America as in Europe.[24]

As late as 1916 seeds could still be obtained in Iowa of what was yet known as the "snake cucumber," a curiosity not uncommon in the 1860's which attained a length of four to six feet. It was probably with reference to this same variety, or a forerunner of it, that Jefferson, only six months before his death, revealed his continued interest not only in untried crops but also in the possibilities of plant breeding, when he wrote about his failing health and

> "to request further that you will procure for me and send in a letter by mail half a dozen seeds of these mammoth cucumbers. One of 4 f. 6 i. long, and another of 4f.5¾ should afford so many seeds as to spare a few to a beggar. Altho giants do not always beget giants, yet I should count on their improving the breed, and this vegetable being a great favorite of mine, I wish to take the chance of an improvement."[25]

AGRICULTURAL OBSERVATIONS IN EUROPE

In the spring of 1787, while serving as American Minister in France, Jefferson made a rather extensive journey into the southern parts of that country and into northwestern Italy, partly for the purpose of visiting the famous watering place of Aix. In his characteristically detailed manner he assembled numerous notes of agricultural practices and of the local flora in the provinces and towns through which he passed. These accounts, though sketchy, provide us today with some interesting observations on conditions in France and Italy at the close of the eighteenth century, not only with respect to agriculture and related topics, but also regarding the physiography of the country, the people and their industries. They cover an amazing variety of topics, as did all of Jefferson's observations, and we can readily

[23] Letter to George Fleming, December 29, 1815 (13, XIV, *365*).
[24] Letter to Samuel Maverick, May 12, 1822 (15, *270*).
[25] Letter to Thomas Worthington, November 29, 1825 (15, *298*).

imagine him rolling along the dusty or muddy roads of the country in the horse-drawn vehicles of those days, tarrying at wayside inns and subjecting their keepers or other townspeople to questioning for information on nearly every topic that one might think of. It is in his notes regarding plants, of course, that we are particularly interested, and from them we gather the following picture.[26]

From Sens to Vermanton, in the province of Champagne, which has since been subdivided, the plains were in corn and the hills in vineyards. A few apple trees dotted the landscape, but there was none of any other kind. In Burgundy, one of the oldest viticultural districts of Europe, also subdivided since Jefferson's visit, there was more of interest and worthy of noting. All the hills were in corn[26a]; there were scattered areas of forest and wood, and, more specifically, of broom,[27] whins[28] and holly,[29] as well as inclosures of what Jefferson called quick hedge. In Dijon he found the best round potatoes that he had ever seen.

At the time of his visit in Burgundy, the first week in March, the peasants were planting, pruning and sticking their vines. Whenever a new vineyard was made the vines were planted in gutters about four feet apart, and as the vines advanced the peasants lay them down. As the vines put out new shoots, they filled all intermediate spaces, until all trace of order was lost and only about one square foot of open soil remained about each plant. They began to yield good profits in five or six seasons and lived up to 150 years. Manufacture of the famous Burgundy wines as well as of other kinds in the regions through which he passed, and the economics of their production occupied much of Jefferson's attention, but his accounts of those aspects are beyond our immediate interest.

In Beaujolois, another former subdivision of France, Jefferson found very little forest, the hillside vineyards inclosed in dry stone walls and the plains in fields of corn. The rotation of crops practiced by the peasants involved wheat the first year, small grains plus red clover the second, and all clover the third. The spontaneous pasturage of green sward was known to the natives as "fromenteau." Jefferson was impressed by the combined cultivation of vines, trees and grain in this part of France. Rows of fruit trees were planted about 20 feet apart, and between them in the rows were espaliered vines four feet apart. The intervals were sown in grain and pasture in alternate years. In Dauphiné, he was told, vines were planted only at the roots of trees and permitted to climb the trees, a practice which, he wrote, spoiled both the fruit and the wine.

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[26] "Memoranda taken on a Journey from Paris into the Southern Parts of France, and Northern of Italy, in the year 1787" (13, XVII, *153–236*).

[26a] Jefferson used the term "corn" in the Old World sense, i.e., as meaning "grain" and including wheat, rye, and barley.

[27] *Cytisus scoparius.*

[28] *Ulex europaeus.*

[29] *Ilex Aquifolium.*

Wild gooseberries at this time (second week in March) were in leaf, wild pear and sweet briar in bud, and in Lyons almond trees were in bloom.

In Dauphiné, another ancient province, Jefferson was struck by what he described as the savage aspect of the country along both sides of the Rhone. The hand of man had subdued the scene, he wrote, "by planting corn where there is little fertility, trees where there is still less and vines where there is none." In the neighborhood of Lyons there was more corn than wine; toward Tains, more wine than corn; and beyond the latter, the extensive plains of the Rhone, where best, were in corn, clover, almonds, mulberries and walnuts. There were also some oaks, the hills were in vines, and near Lyons, but not much afterwards, was a good deal of forest wood. Where the hills were quite in waste, as he described them, they were covered with broom, whins, box and some clusters of small pine. Almond was in general bloom (March 15–18) and willows were putting out their leaves.

At Pains there had formerly been olive trees, but since a great cold some years before had killed them, they had not been replaced.

In Montelimart, too, the peasants planted corn with their vines; they grew an abundance of potatoes and other vegetables; and used walnut oil with their salad. Here, as elsewhere in France, vineyards were fertilized with dung gathered along the roadside, the collecting of which constituted a form of trade.

In the Principality of Orange the plains of the Rhone, two or three leagues wide, were also in corn, clover and almonds, and it was here that the country of olives began. They were the only trees which Jefferson saw planted among the vines. On the hills, thyme grew wild.

In Languedoc forests were absent but cultivated crops included corn, clover, lucerne,[30] St. Foin,[31] olives, mulberries, willows for firewood and hoops, and some almonds. In parts, the waste hills were covered with thyme, box and chêne-vert.[32] At Nîmes the peasants were pruning their olive trees (March 23), a good specimen of which would yield 60 pounds of fruit and 15 pounds of oil. In 1767 a cold spell of a week had killed all the olive trees, but next year the roots produced sprouts. Horse chestnut and mulberry trees were leafing, apple trees and peas blossoming, and from the joints of the Pont du Gard wild figs were flourishing.

The country about Aix was luxuriant, waving in vines, pastures of green sward and clover. There were perfect groves of olive trees and mixed among them were corn, lucerne, and vines. Waste ground threw out thyme and lavender. Firewood of the peasants consisted of chêne-vert and willow, and

[30] Lucerne = alfalfa.

[31] Sainfoin or Saintfoin, a forage crop grown to some extent today in the southern United States, is *Onobrychis viciaefolia*, a segregate from *Hedysarum*.

[32] *Quercus ilex*.

plantings of the latter were lopped every three years. The peasants made their bread half wheat, half rye, and ate it in the mornings with an anchovy or an onion. Their vegetables were always eaten with oil and vinegar, and they drank piquette, made by pouring hot water over the pomace of pressed grapes.

Marseille, too, was the center of great olive groves, interplanted with corn, vines, lucerne, mulberry, almond and willow. Jefferson was informed that the olive grew nowhere more than 30 leagues from the sea, but he doubted that this was true of Spain, Portugal, Asia, and Africa, and expected that it would not apply to America. This last thought was important, as we shall later note, in his attempts to introduce olive culture into his native land.

The finest figs of Europe, Jefferson informs us, grew about Marseille, and were known as "figues Marcelloises" or "les veritables Marcelloises," to distinguish them from others of inferior quality. The figs were formed on the trees around the first of April and would keep any length of time, whereas others would exude a sugar in the spring and become sour. The Marseille fig, Jefferson was told, would degenerate if transplanted into any other part of the country. There were also a few trees of a small seedless grape from Smyrna, and the best of all grapes for drying was known as "des Panses." They were very large with a thick skin and much juice, growing best against walls of southern exposure.

Gathering mulberry leaves constituted another means of earning a living, and caper buds[33] had to be collected every day as they formed, a labor that was performed by women. Pistache, too, grew in the neighborhood but not so well, and the peasants ate the fruits in the milky state. By the middle of March the people were cutting asparagus; they had Windsor beans on April 4; the next day Jefferson saw strawberries and the Guelder rose in blossom. Raisins were first dipped in lye and then dried in the sun to preserve them. Aloe grew in the open ground.

Jefferson mentions oranges first in the little village of Olioules, outside Marseille, and around Cuges capers were abundantly cultivated. From Olioules to Toulon, figs were in the open fields, some with stems 15 inches in diameter. They generally forked near the ground but some had single stems five feet long. The plants were large as apricot trees, and the olive trees about the size of large apple trees. Corn and almonds, too, were grown, as well as capers. The latter were planted eight feet apart, and the fruits, as already mentioned, were gathered by women, beginning about the last of June and continuing until the middle of October. Each plant had to be picked every day, and they grew equally well in the best or worst soil, even

[33] Pickled flower buds of the caper bush, *Capparis spinosa*, have long been used as a condiment and ingredient of sauces in the Old World.

in walls where there seemingly was none. Their life-span was that of a man or longer. Peas were available through the winter, occasionally under shelter, and they had been so without shelter since March 25.

At Hières, in addition to the usual olives, mulberries, vines, figs and corn, there were also some flax and cherry trees. Groves of fruit trees extended two or three miles from the town to the sea, and in them were orange trees of two feet diameter one way, one foot the other, the contour of all the larger trunks being oval rather than circular. The largest trees were 20 feet tall and yielded about 6,000 oranges per year. The leaves of many and some trees themselves had been killed by cold the previous November. One garden which Jefferson visited had about 15,600 trees, eight to ten feet apart, which blossomed and bore fruit at the same time and in every stage all year round. The best fruit was that which was gathered in April and May. There were also palm trees in Hières, 20 or 30 feet tall, but they bore no fruit, and the King kept a botanical garden here, concerning which Jefferson does not give us any details.

Beyond Hières, in addition to the customary crops of the region, were hedges of pomegranate, sweet briar and broom, and a great amount of thyme was growing wild. At Antibes and Nice oranges were in the open, but in small high inclosures and were protected by the neighboring mountains. This was true also of the oranges at Olioules, and Jefferson was induced to write that the climate seemingly did not permit their cultivation without shelter anywhere on the French side of the Alps.

Beyond Nice, as Jefferson journeyed through the Maritime Alps into Italy, oranges were no longer to be seen, and the olive was lost a little above the village of Scarena on Mount Braus, to be met again on the other side a little above the town of Sospelo. Wherever there was sufficient soil, the land was terraced and in grain, and waste areas were either in two-leaved pines or denuded. Likewise, in crossing Mount Brois near Ciandola and Tende, olives were lost at a certain height but found again on the other side at the village of Breglio. On the lowland there were also corn, vines, mulberries, figs, cherries and walnuts. At the village of Fontan olives disappeared and chestnut trees began in good quantities. About Limone and Coni, wherever there was sufficient soil on the mountains, corn was cultivated "quite to the commencement of the snows" on the mountains. Waste parts were in two-leaved pines, lavender and thyme. The plains near Coni were in pastures, corn, mulberries, and some almonds, and along the rivers was a great deal of golden willow.

At this point in his notes Jefferson makes the following interesting observation:

"The southern parts of France, but still more the passage through the Alps, enable one to form a scale of the tenderer plants, arranging them

according to their several powers of resisting cold. Ascending three different mountains, Braus, Brois, and Tende, they disappear one after another; and descending on the other side, they show themselves again one after another. This is their order, from the tenderest to the hardiest. Caper, orange, palm, aloe, olive, pomegranate, walnut, fig, almond. But this must be understood of the plant; for as to the fruit, the order is somewhat different. The caper, for example, is the tenderest plant, yet being so easily protected, it is the most certain in its fruit. The almond, the hardiest plant, loses its fruit the oftenest, on account of its forwardness. The palm, hardier than the caper and the orange, never produces perfect fruit in these parts."[34]

From the mountains to Turin the walnut was the tenderest tree that survived, and of it as well as of almond and mulberry trees there were only a few. Grapes were more abundant, but most plentiful were willows and poplars. Corn, clover, and small grass were mixed with them, and the rich soil of the country was generally infested with wild onions. At Racconigi there was some cultivation of corn, but what attracted Jefferson most is thus expressed in his own words:

"They have a method of planting the vine, which I have not seen before. At intervals of about eight feet, they plant from two to six plants of vine in a cluster. At each cluster they fix a forked staff, the plane of the prongs of the fork at a right angle with the row of vines. Athwart these prongs they lash another staff, like a handspike, about eight feet long, horizontally, seven or eight feet from the ground. Of course, it crosses the rows at right angles. The vines are brought from the foot of the fork up to this cross piece, turned over it, and conducted along over the next, the next, and so on, as far as they will extend, the whole forming an arbor eight feet wide and high, and of the whole length of the row, little interrupted by the stems of the vines, which being close around the fork, pass up through hoops, so as to occupy a space only of small diameter."[35]

Continuing on through other towns to Vercelli, cultivation of corn, pasture, maize, vines, mulberries, walnuts, willow and poplar continued. The peasants made hedges of willow by setting the plants one to three feet apart and bending them down to interlace with one another when they were eight or ten feet tall. None of these hedges appeared very old to Jefferson, and he concluded therefore that they soon died.

The Italian rice fields began in the neighborhood of Vercelli, whence Jefferson procured seed, as later related, for introduction into South Carolina. He noted that the water with which the fields were irrigated was very clear and that sowing of rice within two miles of cities was not permitted, on account of "insalubrity." Notwithstanding, Jefferson wrote, when the water was drawn off the fields in August, the whole country became subject to agues and fevers. The peasants estimated that the same measure of

[34] (13, XVII, *187.*)
[35] (13, XVII, *188.*)

ground yielded three times as much rice as wheat, and with half the labor. They were sowing their rice at the time of Jefferson's visit, April 19, and as soon as sowed, the fields were flooded, two or three inches deep. Six weeks or two months later, the water was drawn off to permit weeding. The fields were then flooded again and allowed to remain so until August, three or four weeks before the grain was ripe. In September the rice was cut, threshed, beaten in mortars to separate the husks, and then sifted into different qualities.

From Vercelli to Novara the fields were all in rice and mostly under water, and the dams separating several ponds were planted with willows. There were some figs in well-protected spots in Novara, but from there to Ticino the country was, for the most part, stony and waste, grown up in broom. From Ticino to Milan all was in corn, interplanted with willows, many mulberries, some walnuts, and here and there an almond. Nearing Milan, Jefferson was induced to write:

"They have still another method here of planting the vine. Along rows of trees, they lash poles from tree to tree. Between the trees are set vines, which, passing over the pole, are carried on to the pole of the next tree, whose vines are in like manner brought to this, and twined together, thus forming the intervals between the rows of trees alternately into arbors and open spaces. They have another method also of making quick-set hedges. Willows are planted from one to two feet apart, and interlaced, so that every one is crossed by three or four others."[36]

Figs and pomegranates, Jefferson was told, grew unsheltered in Milan, but seeing none, he supposed they were rare. Olives had formerly grown there, but since a great cold in 1709 had killed them, they had not been replaced. In fact, the nights that Jefferson was in Milan, April 21 and 22, the rice ponds froze half an inch thick. Such ponds were not permitted within five miles of this city, and the intervening country was in corn, pastures, gardens, mulberries, willows and vines.

Butter and Parmesan cheese manufacture centered about Lodi and are carefully described in Jefferson's notes, one interesting detail of which is that an ounce of saffron, the dye secured from the dried, orange-colored stigmas of the locally native *Crocus sativus*, was added to seven brenta [brenta = 50 liters] of milk to give color to the cheese. [An ounce of saffron requires the stigmas of more than 4,000 flowers.]

At Novi the Apennines began to rise, their growth consisting of oak and chestnut. Walnut was soon lost in ascending the mountains but found again about one-fourth of the way down the other side. Half-way down, figs and vines were met, continuing in great abundance to the lowland. Between the mountains and Genoa, olive culture began again, and in the

[36] (13, XVII, *193.*)

immediate environs of the city were strawberries, figs, oranges, mulberries, and corn. Aloe grew in many places but never flowered.

Near Oneglia were many trees known as carroubier which Jefferson knew had been named *Ceratonia siliqua* by Linnaeus, a name that is still valid. These trees were, of course, the well-known carobs whose pods, as Jefferson learned, furnished food for horses, and also for the poor peasants in times of scarcity. At St. Remo orange and lemon trees were in abundance, and farther along toward Monaco and Nice were extensive plantations of palm trees. The midribs of these palms, Jefferson wrote, were in such demand in Rome on Palm Sundays, that cultivation here to meet that demand was a profitable enterprise.

Later, in France again, Jefferson found St. Foin extensively cultivated around Montpelier and known there as sparsette. There was also a great deal of madder or garance, *Rubia tinctorum*, the raising of which was said to be immensely profitable. In Jefferson's words:

"The first four years of madder are unproductive; the fifth and sixth yield the whole value of the land. Then it must be renewed. The sparsette is the common or true St. Foin. It lasts about five years; in the best land it is cut twice, in May and September, and yields three thousand pounds of dry hay to the setterie the first cutting, and five hundred pounds the second. . . . Lucerne is the best of all forage; it is sowed here in the broadcast, and lasts about twelve or fourteen years. It is cut four times a year, and yields six thousand pounds of dry hay at the four cuttings, to the setterie."[37]

In Cette, wine manufacture was the principal industry, as in most of the adjacent country, and it furnished great quantities of grape pomace for making verdigris.[38] At Carcassonne flax was in bloom (May 18) and Windsor beans had just come to the table, but there were not yet either strawberries or peas. At one point in this vicinity Jefferson noted what he said were the last olive trees, and in his memoranda he indulged in the following discussion with himself, so characteristic of his inquiring mind and devotion to detail:

"On a review of what I have seen and heard of this tree, the following seem to be its northern limits. Beginning on the Atlantic, at the Pyrenees, and along them to the meridian of la Lande, or of Carcassonne; up that meridian to the Cevennes, as they begin just there to raise themselves high enough to afford it shelter. Along the Cevennes, to the parallel of forty-five degrees of latitude, and along that parallel (crossing the Rhone near the mouth of the Isere) to the Alps; thence along the Alps and Apennines, to what parallel of latitude I know not. Yet here the tracing of the line becomes

[37] (13, XVII, *207*.)

[38] Verdigris is a green pigment, known to the ancient Romans, used in dyeing and medicine, and much produced in the wine districts of France by exposing thin strips of copper to acetic acid developed in the residues from wine factories.

the most interesting. For from the Atlantic, so far, we see this production the effect of shelter and latitude combined. But where does it venture to launch forth unprotected by shelter, and by the mere force of latitude alone? Where for instance does its northern limit cross the Adriatic? I learn that the olive tree resists cold to eight degrees of Reaumur below the freezing point, which corresponds to fourteen above zero of Fahrenheit; and that the orange resists to four degrees below freezing of Reaumur, which is twenty-three degrees above zero of Fahrenheit."[39]

This concern of Jefferson in wanting to know where latitude alone permitted olive cultivation was not merely academic; it had a very practical bearing, and, as we shall soon note, Jefferson later instructed Edward Rutledge to secure additional information on the subject, for he was interested in promoting olive culture in America.

The vineyards and production of wine in the neighborhood of Bordeaux occupy several pages of Jefferson's notes. In the surrounding country he found vines, corn, maize, farouche,[40] clover, lucerne, apples, cherries, and waste areas in furze[41] and broom.

At Nantes, Carolina rice, a topic to be discussed later in considerable detail, was preferred to that of Lombardy for the Guinea trade because it required less water to boil.

Ascending the Loire from Nantes, Jefferson found the countryside as far as Angers in grain, pasture, vines, some maize, flax, and hemp. Beyond Nantes there were, in addition, many willows, poplars, and walnuts. The flax was nearly ripe (June 8), and sweetbriar was generally in bloom. There was still some broom on which the cattle and sheep browsed in winter and spring when they had no other green food. Hogs ate the blossoms and pods in spring and summer. The first crop of hay was being cut, and with a passing remark upon vineyards and wine production in the region, Jefferson concluded his agricultural observations on this journey in 1787.

The next spring he visited the Rhineland, but his notes from that journey are devoted primarily to other matters than plant life. There are, of course, the customary observations on vineyards and manufacture of wines, but the only remarks of particular interest to us are the following. Cologne, at that time a sovereign city of about 60,000 inhabitants and having no territory outside its walls, was the most northern spot on earth where wine was made. Their first grapes had originally come from Orleans, but since then others had been brought from Alsace and Champagne. Jefferson also informs us that it was only 32 years since the first vine had been sent from Cassel, near Mayence, to the Cape of Good Hope, where Cape wine was made as a consequence. The Cape, Jefferson supposed, was the most southern spot on

[39] (13, XVII, *214.*)
[40] *Trifolium incarnatum.*
[41] Furze = whin, *Ulex europaeus.*

earth where wine was made, and he regarded it as singular that the same vine should have furnished two wines as much opposed to each other in quality as they were apart in location.

In Heidelberg, apple, pear, cherry, peach, apricot, and almond were all in bloom (April 14), and at the village of Kaeferthal was a plantation of rhubarb, started in 1769, which supplied the apothecaries of Frankfort and England.

INTRODUCTION OF NEW CROP PLANTS INTO AMERICA

As a result of his long sojourn in France and especially of his having seen so much of the agricultural activities there, Jefferson became imbued with the idea that certain crop plants of Europe, theretofore not cultivated in the States, should be introduced into America. His enthusiasm in this direction became so great and so enduring that years later in an appendix to his autobiography, begun in 1821 at the age of 77, he concluded with the very strong statement that

"The greatest service which can be rendered any country is, to add an useful plant to its culture; especially, a bread grain; next in value to bread is oil."[42]

On an earlier occasion, when thanking someone for some seeds of the breadfruit tree to be introduced into the southern States, he concluded with the remark that

"One service of this kind rendered to a nation, is worth more to them than all the victories of the most splendid pages of their history, and becomes a source of exalted pleasure to those who have been instrumental to it. May that pleasure be yours, and your name be pronounced with gratitude by those who will at some future time be tasting the sweets of the blessings you are now procuring them."[43]

What he advocated, he practiced himself, and scarcely left a stone unturned which held any promise of adding to the vegetative richness of his homeland. We have already observed in our consideration of his farming activities that he imported legumes from abroad to restore fertility to his soil, and our attention now becomes directed to a variety of other plants.

In 1786, while still in Paris, Jefferson had occasion to acknowledge election to membership in the South Carolina Agricultural Society which had been organized the previous year and with which he thereafter carried on considerable correspondence. In reciprocation for the honor thus accorded him, he expressed the hope of being able to render some service

"by forwarding to the society such new objects of culture, as may be likely to succeed in the soil and climate of South Carolina. In an infant country,

[42] (13, I, *259*.)

[43] Letter to Mr. Giroud, May 22, 1797 (13, IX, *387*).

as ours is, these experiments are important. We are probably far from possessing, as yet, all the articles of culture for which nature has fitted our country. To find out these, will require abundance of unsuccessful experiments. But if, in a multitude of these, we make one useful acquisition, it repays our trouble. Perhaps it is the peculiar duty of associated bodies, to undertake these experiments. Under this sense of the views of the society, and with so little opportunity of being otherwise useful to them, I shall be attentive to procure for them the seeds of such plants, as they will be so good as to point out to me, or as shall occur to myself as worthy of their notice. I send at present, by Mr. McQueen, some seeds of a grass, found very useful in the southern parts of Europe, and particularly, and almost solely cultivated in Malta. It is called by the names of Sulla, and Spanish St. Foiń, and is the *Hedysarum coronarium*[44] of Linnaeus. It is usually sown early in autumn. I shall receive a supply of fresher seed, this fall, which I will also do myself the honor of forwarding to you. I expect, in the same season, from the south of France, some acorns of the cork oak, which I propose for your society, as I am persuaded they will succeed with you. I observed it to grow in England, without shelter; not well, indeed, but so as to give hopes that it would do well with you."[45]

Two years later Jefferson was promising more seed of the Spanish St. Foin, some of which he had received by then direct from Malta.[46] He fulfilled his promise, but the shipment apparently was lost at sea, for years later he bemoaned this failure.[47] In the same letter we learn also of similar disappointment in regard to the other plant mentioned in the above quoted correspondence:

"I have been long endeavoring to procure the Cork tree from Europe, but without success. A plant which I brought with me from Paris died after languishing some time, and of several parcels of acorns received from a correspondent at Marseilles, not one ever vegetated. I shall continue my endeavors, although disheartened by the nonchalance of our Southern fellow citizens, with whom alone they can thrive."[47]

In 1808 Jefferson received

"a bottle of the oil of Beni,[48] believed to be a sesamum. I did not believe there existed so perfect a substitute for olive oil. Like that of Florence, it has no taste, and is perhaps more limpid. A bushel of seeds yields three gallons of oil; and Governor Milledge, of Georgia, says the plant will grow wherever the Palmi Christi will. It is worth your attention, and you can probably get seed from Colonel Fen."[49]

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[44] This European herb, valued as forage, is sometimes cultivated for its pink flowers as French honeysuckle.

[45] Letter to William Drayton, May 6, 1786 (13, V, *311*).

[46] Letter to William Drayton, January 13, 1788 (13, VI, *413*).

[47] Letter to James Ronaldson, January 12, 1813 (13, XIII, *204*).

[48] Sesame or Benne oil, from *Sesamum indicum*, is one of the staple food oils of India, and has limited use in salads, soaps and pharmaceuticals.

[49] Letter to R. R. Livingston, January 3, 1808 (13, XI, *411*).

Three days later he wrote to another correspondent and informs us that

"The African Negroes brought over to Georgia a seed which they called beni, and the botanists sesamum. I lately received a bottle of the oil, which was eaten with salad by various companies. All agree it is equal to the olive oil. A bushel of seeds yields three gallons of oil. I propose to cultivate it for my own use at least."[50]

In this same letter Jefferson called attention to a report in the transactions of the Agricultural Society of Paris that they were cultivating Jerusalem artichoke for animal feed, 10,000 pounds to the acre, which they said was three times as much as they generally made of potatoes. His efforts with the beni seeds were not very successful:

"I sowed some of the Benni seed the last year, and distributed some among my neighbors; but the whole was killed by the September frost. I got a little again the last winter, but it was sowed before I received your letter. Colonel Fen of New York receives quantities of it from Georgia, from whom you may probably get some through the Mayor of New York. But I little expect it can succeed. It is about as hardy as the cotton plant, from which you may judge of the probability of raising it at Hudson."[51]

Culture of the almond tree, Jefferson wrote from France, was so precarious that no one but persons of capital could depend on it for subsistence,[52] and the fig and mulberry were so well known in America that nothing needed to be said about them. Since the latter two were cared for in France by women and children, Jefferson looked upon them, in contemplating conditions in America, as

"earnestly to be desired in countries where there are slaves."[52]

Capers also attracted Jefferson's attention in Europe, and in 1792 he imported some from Marseille. He sent them to Charleston[53] for trial there and expressed the opinion that they would probably succeed in America, that their culture would offer a very great and immediate profit.[54] He also wrote:

"The caper, though a more tender plant, is more certain in its produce, because a mound of earth of the size of a cucumber hill, thrown over the plant in the fall, protects it effectually against the cold of winter. When the danger of frost is over in the spring, they uncover it, and begin its culture. There is a great deal of this in the neighborhood of Toulon. The plants are set about eight feet apart, and yield, one year with another, about two pounds of caper each, worth on the spot sixpence sterling per pound. They require little culture, and this may be performed either with the plough or hoe. The principal work is the gathering of the fruit as it forms. Every plant must be

[50] Letter to John Taylor, January 6, 1808 (13, XI, *413*).
[51] Letter to Horatio G. Spafford, May 14, 1809 (13, XII, *278*).
[52] Letter to William Drayton, July 30, 1787 (13, VI, *193*).
[53] Letter to George Washington, May 16, 1792 (13, VIII, *337*).
[54] Letter to Edward Rutledge, July 14, 1787 (13, VI, *169*).

picked every other day, from the last of June till the middle of October. But this is the work of women and children. This plant does well in any kind of soil which is dry, or even in walls where there is no soil, and it lasts the life of a man. Toulon would be the proper port to apply for them. I must observe, that the preceding details cannot be relied on with the fullest certainty, because, in the canton where this plant is cultivated, the inhabitants speak no written language, but a medley, which I could understand but very imperfectly."[55]

The foregoing economic plants, while interesting in having appealed to Jefferson, were really secondary in his considerations. For the important items we must refer to the quotation on page 585 at the beginning of this chapter. That sentence was part of one of eleven paragraphs constituting what Jefferson called "Note G" in the Appendix to his autobiography, those eleven paragraphs being devoted to that number of items of his accomplishments, in an attempt to answer the question in his own mind whether his country was any better for his having lived. This note, apparently, was never completed. It briefly mentioned disestablishment of a State church, abolition of entails and prohibition of slave importation, and the greatest of all was only named, "The Declaration of Independence." The Lewis and Clark Expedition was not even mentioned, though Jefferson's successful promotion of that project, as we shall later note, was his foremost contribution to science; it undoubtedly would have been included had that note ever been completed. It is because of this omission that we find particular significance in his having included, so far as he did formulate that note, the following two paragraphs:

"In 1789 and 1790, I had a great number of olive plants, of the best kind, sent from Marseilles to Charleston, for South Carolina and Georgia. They were planted, and are flourishing; and, though not yet multiplied, they will be the germ of that cultivation in those States.

In 1790, I got a cask of heavy upland rice, from the river Denbigh, in Africa, about lat. 9° 30′ North, which I sent to Charleston, in hopes it might supersede the culture of the wet rice, which renders South Carolina and Georgia so pestilential through the summer. It was divided, and a part sent to Georgia. I know not whether it has been attended to in South Carolina; but it has spread in the upper parts of Georgia, so as to have become almost general, and is highly prized. Perhaps it may answer in Tennessee and Kentucky."[56]

Because of the importance which Jefferson thus attached to these two incidents, so briefly mentioned in the closing years of his life, it is most appropriate that we carefully examine all his previous correspondence which may shed any light on the two topics. From them we acquire the following picture.

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[55] Letter to William Drayton, July 30, 1787 (13, VI, *193*).

[56] (13, I, *258*.)

Rice.[57] While in France as American Minister to that country, Jefferson observed that the annual consumption of rice, particularly in Paris, was considerable, amounting to about 82,000 quintals (quintal = 220 pounds), and he regarded it as his duty to determine what the sources of supply were, to what extent the material was imported from America, where it had been in cultivation since the latter part of the sixteenth century, and whether the American proportion of that supply could not be increased. Difficulties were encountered in his attempts to secure accurate information on these matters from retailers of rice, but his persistent inquiries finally produced the following information.

The dealers in France were in the habit of selling two qualities of rice, one from Carolina with which they were supplied chiefly from England; the other known as Piedmont rice from Italy. The Carolina rice was long, slender, attractively white, and served well when prepared *au lait*, that is, with milk and sugar, but not so well when prepared in a fashion known as *au gras*. That of Piedmont was shorter, thicker and less white, but was the better when served *au gras*. It was preferred, therefore, to the American rice, though the more pleasing appearance of the latter resulted in its imports from America being approximately equal to those from Piedmont.

The difference in quality between the two kinds, accounting for the preference exhibited toward that from Piedmont, was attributed by the rice dealers to a difference in techniques between the American and French methods of preparing the material for market. The Carolina rice, they figured, was husked with a type of machine that broke it more than did the French instrument, and less care was observed in separating the broken from the unbroken grains. The Carolina rice was less expensive to the dealers than that of Piedmont, but since they were obliged to sort the whole grains from the broken, in order to satisfy the taste of their customers, the dealers had to charge as much for the first quality Carolina rice, when sorted, as for that of Piedmont. Second and third qualities, obtained by sorting, sold much cheaper.

Mechanically inclined as Jefferson was, among his many accomplishments, he determined to learn in what way the machines of Piedmont differed from those of South Carolina and why they supplied the European market

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[57] Account gathered from letters to (all in citation No. 13):
John Jay, January 2, 1786 (VII, *28*); May 4, 1787 (VI, *111*).
Edward Rutledge, July 14, 1787 (VI, *169*); July 18, 1788 (VII, *79*); September 18, 1789 (VII, *463*).
Dr. David Ramsay, October 27, 1786 (V, *455*).
John Adams, July 1, 1787 (VI, *146*).
James Maury, November 13, 1787 (VI, *374*).
George Washington, December 4, 1788 (VII, *223*).
Benjamin Vaughan, May 17, 1787 (VII, *359*); June 27, 1790 (VIII, *49*).
Ralph Izard, August 1, 1787 (VI, *209*).

with rice which was less broken than that from America. It was in connection with his journey into southern France in 1787 that an opportunity presented itself for acquiring this information. Frustrated at first in his attempt to learn the answer in Marseille, which was the great emporium of the Levant and of Italy, he set out that year on a three-weeks journey across the Alps into the rice country of Italy between Vercelli and Pavia. There he visited the rice fields of the Venellese and Milanese, saw their machines in operation, and found them almost identical with those of Carolina. He thereupon concluded that the Italian rice which, incidentally, came from Lombardy and not Piedmont as incorrectly implied in its common name, was of a species different in form, color and quality from that of Carolina. He founded this conclusion partly on the reports of a certain M. Poivre, a former Governor of the Isle of France, who had travelled through several countries of Asia, observing in particular the agriculture of those lands. He had written upon rice and reported six kinds as being cultivated in Cochin China, three of them requiring water and three being of the upland type, growing on highlands. According to Poivre, Carolina rice was of the "white" variety, different from these, and Jefferson understood, as we know today, that it had originally come from Madagascar. The effect of time, culture, and climate, Jefferson thought, may have accentuated any original differences between the Carolina and Lombardy strains.

It is only natural that Jefferson should have then become interested in the prospects of getting some of the unhusked rice of Piedmont or Lombardy, as one may prefer to call it, to America in order that its cultivation here might be undertaken. But the government of Turin, in the vicinity of which the finest strains were grown, prohibited its export in that form on pain of death. To circumvent this restriction, Jefferson resorted to a little smuggling activity by engaging a muleteer to run a couple of sacks across the Apennines to Genoa, beyond which their further transit would not have been so precarious.[58] Jefferson was skeptical of the success of this venture and so he filled his coat and surtout pockets with a few pounds of the best kind he could obtain from Vercelli. These he sent to William Drayton of the agricultural society in South Carolina, not in one package but in three parcels by as many different ways to be assured of their delivery. The fate of the shipment entrusted to the mule is not revealed in any of Jefferson's letters, but the other three bundles from Turin, we know, arrived safely in Charleston. Their contents were distributed among the rice growers of the South, ten and twelve grains to each of several planters.

Jefferson was not satisfied, however, merely with this smuggling exploit. He continued his investigations and the next year he informed Dr. Drayton

[58] In his own words: "Poggio, a muleteer, who passes every week between Vercelli and Genoa, will smuggle a sack of rough rice for me to Genoa; it being death to export it in that form" (13, XVII, *192*).

that another kind of rice obtainable from the Levant was considered by some not only to be different in quality from that of Piedmont but even as superior to it. He sent a quantity of this strain in the husked form to Dr. Drayton, and took measures to obtain unhusked grains of it for him. In reference to the American and Old World varieties he then continued:

"I should think it certainly advantageous to cultivate, in Carolina and Georgia, the two qualities demanded at market; because the progress of culture, with us, may soon get beyond the demand for the white rice; and because too, there is often a brisk demand for the one quality, when the market is glutted with the other. I should hope there would be no danger of losing the species of white rice, by a confusion with the other. This would be a real misfortune, as I should not hesitate to pronounce the white, upon the whole, the most precious of the two, for us. The dry rice of Cochin-China has the reputation of being the whitest to the eye, best flavored to the taste, and most productive. It seems then to unite the good qualities of both the others known to us. Could it supplant them, it would be a great happiness, as it would enable us to get rid of those ponds of stagnant water, so fatal to human health and life. But such is the force of habit, and caprice of taste, that we could not be sure beforehand it would produce this effect. The experiment, however, is worth trying, should it only end in producing a third quality, and increasing the demand. I will endeavor to procure some to be brought from Cochin-China. The event, however, will be uncertain and distant."[59]

Six months later he sent some rough rice for experimental purposes from Egypt, and remarked that the young Prince of Cochin China, who had recently left Paris and with whom Jefferson had presumably become acquainted, promised to send him some dry rice from that country.[60] It is from a letter of 20 years later, however, that we learn of his final success in introducing into the States a type of upland rice from the River Denbigh in Africa:

"In answer to the inquiries of the benevolent Dr. De Carro on the subject of the upland or mountain rice, *Oryza Mutica*, I will state to you what I know of it. I first became informed of the existence of a rice which would grow in uplands without any more water than the common rains, by reading a book of Mr. De Poivre, who had been Governor of the Isle of France, who mentions it as growing there and all along the coast of Africa successfully, and as having been introduced from Cochin-China. I was at that time (1784–89) in France, and there happened to be there a Prince of Cochin-China, on his travels, and then returning home, I obtained his promise to send me some. I never received it however, and mention it only as it may have been sent, and furnished the grounds for the inquiries of Dr. De Carro, respecting my receiving it from China. When at Havre on my return from France, I found there Captain Nathaniel Cutting, who was the ensuing spring to go on a voyage along the coast of Africa. I engaged him to inquire for this; he was there just after the harvest, procured and sent me a thirty-gallon

[59] Letter to William Drayton, July 30, 1787 (13, VI, *193*).
[60] Letter to William Drayton, January 13, 1788 (13, VI, *413*).

cask of it. It arrived in time the ensuing spring to be sown. I divided it between the Agricultural Society of Charleston and some private gentlemen of Georgia, recommending it to their care, in the hope which had induced me to endeavor to obtain it, that if it answered as well as the swamp rice, it might rid them of that source of their summer diseases. Nothing came of the trials in South Carolina, but being carried into the upper hilly parts of Georgia, it succeeded there perfectly, has spread over the country, and is now commonly cultivated; still, however, for family use chiefly, as they cannot make it for sale in competition with the rice of the swamps. The former part of these details is written from memory, the papers being at Monticello which would enable me to particularize exactly the dates of times and places. The latter part is from the late Mr. Baldwin, one of those whom I engaged in the distribution of the seed in Georgia, and who in his annual attendance on Congress, gave me from time to time the history of its progress. It has got from Georgia into Kentucky, where it is cultivated by many individuals for family use. I cultivated it two or three years at Monticello, and had good crops, as did my neighbors, but not having conveniences for husking it, we declined it. I tried some of it in a pot, while I lived in Philadelphia, and gave seed to Mr. Bartram. It produced luxuriant plants with us both, but no seed; nor do I believe it will ripen in the United States as far north as Philadelphia."[61]

In Jefferson's correspondence regarding rice there is an incidental though interesting reference to the famous Captain Bligh of Bounty fame. Captain Bligh, in charge of the ship Bounty, had been sent to the South Sea islands to stock breadfruit trees for transplanting into the British West Indies. His allegedly tyrranous management of the crew led to mutiny near the Friendly Islands, and Bligh, with 19 of his men, were set adrift in an open boat. In June, 1789, they landed on the island of Timor, and eventually made their way back to England. Bligh was subsequently commissioned to repeat the voyage and this time succeeded in his commission. The relationship of all this to Jefferson is revealed in a letter to him in 1790 from Jamaica, from one Samuel Vaughan.[62] From it we gather that Jefferson had asked Vaughan's father for some seeds of mountain rice, the request had been transmitted to the son, and the son was replying to the effect that he could not comply but instead was sending 40 seeds, twenty with the letter and twenty otherwise, of a variety of rice that was plentiful in the central parts of Hispaniola. The point is somewhat ambiguous in his letter, but it was probably with reference to this same rice, that Vaughan wrote that the seeds which he had, had been brought from Timor by Captain Bligh. The implication is that Bligh, despite his predicament, brought seed rice with him, and that within a year's time it was abundant in Hispaniola, all of which seems rather unlikely. Nevertheless, Jefferson believed in this origin of the rice, for five months earlier we find him acknowledging receipt

[61] Letter to Dr. Benjamin Waterhouse, December 1, 1808 (13, XII, *204*).
[62] Letter from Samuel Vaughan, Jr., October 4, 1790 (15, *44*).

of some dry rice from the Moluccas, and informing Benjamin Vaughan[63] that some of the seed had been sent to Virginia; the others had been sowed in pots, and at the time of his writing he had 23 young plants, but feared that there was not enough of summer remaining for them to mature.

Despite Jefferson's enthusiasm in the matter, and the assertions of certain biographers that his introduction of dry rice brought prosperity and wealth to parts of the South, we must note that cultivation of upland rice in the United States never became significant.

Olives.[64] Jefferson's interest in olive trees as a crop plant for America was scarcely less intense than that in rice, and his enthusiastic advocacy of their cultivation in the States is well displayed in a letter to Dr. Drayton from Paris in 1787:

"The olive is a tree the least known in America, and yet the most worthy of being known. Of all the gifts of heaven to man, it is next to the most precious, if it be not the most precious. Perhaps it may claim a preference even to bread, because there is such an infinitude of vegetables which it renders a proper and comfortable nourishment. In passing the Alps at the Col de Tende, where they are mere masses of rock, wherever there happens to be a little soil, there are a number of olive trees, and a village supported by them. Take away these trees, and the same ground in corn would not support a single family. A pound of oil, which can be bought for three or four pence sterling, is equivalent to many pounds of flesh, by the quantity of vegetables it will prepare, and render fit and comfortable food. Without this tree, the country of Provence and territory of Genoa would not support one-half, perhaps not one-third, their present inhabitants. The nature of the soil is of little consequence if it be dry. The trees are planted from fifteen to twenty feet apart, and when tolerably good, will yield fifteen or twenty pounds of oil yearly, one with another. There are trees which yield much more. They begin to render good crops at twenty years old, and last till killed by cold, which happens at some time or other, even in their best positions in France. But they put out again from their roots. In Italy, I am told, they have trees two hundred years old. They afford an easy but constant employment through the year, and require so little nourishment, that if the soil be fit for any other production, it may be cultivated among the olive trees without injuring them. The northern limits of this tree are the mountains of the Cevennes, from about the meridian of Carcassonne to

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[63] Letter to Benjamin Vaughan, June 27, 1790 (13, VIII, *49*).

[64] Account founded on letters to (all in citation No. 13):
The President of the United States, May 1, 1791 (VIII, *189*), May 16, 1792 (VIII, *337*).
C. C. Pinckney, October 8, 1792 (VIII, *412*).
Edward Rutledge, July 14, 1787 (VI, *169*), November 19, 1788 (VII, *50*), September 18, 1789 (VII, *463*).
Wm. Drayton, July 30, 1787 (VI, *193*).
George Wythe, September 16, 1787 (VI, *296*).
M. de Bertrous, February 21, 1788 (VI, *431*).
James Ronaldson, January 12, 1813 (XIII, *204*).
Stephan Catalan, December 2, 1792 (XIX, *98*).

the Rhone, and from thence, the Alps and Apennines as far as Genoa, I know and how much farther I am not informed. The shelter of these mountains may be considered as equivalent to a degree and a half of latitude, at least, because westward of the commencement of the Cevennes, there are no olive trees in 43½° or even 43° of latitude, whereas, we find them *now* on the Rhone at Pierrelatte, in 44½°, and *formerly* they were at Tains, above the mouth of the Isere, in 54°, sheltered by the near approach of the Cevennes and Alps, which only leave there a passage for the Rhone. Whether such a shelter exists or not in the States of South Carolina and Georgia, I know not. But this we may say, either that it exists or that it is not necessary there, because we know that they produce the orange in open air; and wherever the orange will stand at all, experience shows that the olive will stand well, being a hardier tree. Notwithstanding the great quantities of oil made in France, they have not enough for their own consumption, and, therefore, import from other countries. This is an article, the consumption of which will always keep pace with its production. Raise it, and it begets its own demand."

"Little is carried to America, because Europe has it not to spare. We, therefore, have not learned the use of it. But cover the southern states with it, and every man will become a consumer of oil, within whose reach it can be brought in point of price. If the memory of those persons is held in great respect in South Carolina who introduced there the culture of rice, a plant which sows life and death with almost equal hand, what obligations would be due to him who should introduce the olive tree, and set the example of its culture. Were the owner of slaves to view it only as the means of bettering their condition, how much would he better that by planting one of those trees for every slave he possessed. Having been myself an eye witness to the blessings which this tree sheds on the poor, I never had my wishes so kindled for the introduction of any article of new culture into our own country. South Carolina and Georgia appear to me to be the States, wherein its success, in favorable positions at least, could not be doubted, and I flattered myself it would come within the views of the society for agriculture to begin the experiments which are to prove its practicability. Carcassonne is the place from which the plants may be most certainly and cheaply obtained. They can be sent from thence by water to Bordeaux, where they may be embarked on vessels bound for Charleston. There is too little intercourse between Charleston and Marseilles to propose this as the port of exportation. I offer my services to the society for the obtaining and forwarding any number of plants which may be desired."

A year later in advising Edward Rutledge concerning things to be noted by the latter during his travels through France, Jefferson was still interested in determining the northern limit of culture of the trees in that country:

"I must press on you, my dear Sir, a very particular attention to the climate and culture of the olive tree. This is the most interesting plant in existence for South Carolina and Georgia. You will see in various places that it gives being to whole villages in places where there is not soil enough to subsist a family by the means of any other culture. But consider it as the means of bettering the condition of your slaves in South Carolina. See in the poorer parts of France and Italy what a number of vegetables are rendered eatable by the aid of a little oil, which would otherwise be useless.

Remark very particularly the northern limits of this tree, and whether it exists by the help of shelter from the mountains, etc. I know this is the case in France. I wish to know where the northern limit of this plant crosses the Apennines; where it crosses the Adriatic and the Archipelago, and if possible what course it takes through Asia."

Jefferson's recommendations, as we might expect, were not without effect, and in another letter from Paris, thanking M. de Bertrous for a book on olive culture which he had just sent to Jefferson, we read:

"This is a precious present to me, and I pray you to accept my thanks for it. I am just gratified by letters from South Carolina, which inform me that in consequence of the information I had given them on the subject of the olive tree, and the probability of its succeeding with them, several rich individuals propose to begin its culture there. It will not interfere with the commerce of France, because she imports much more oil than she exports, and because the consumption of oil in the United States at present, is so inconsiderable, that should their demand be totally withdrawn at the European market, and supplied at home, it will produce no sensible effect in Europe. We can never produce that article in very great quantity, because it happens that in our two southernmost States, where only the climate is adapted to the olive, the soil is so generally rich as to be unfit for that tree, and proper for other productions of more immediate profit."

In two letters of 1792 we learn that the Agricultural Society of South Carolina had also followed Jefferson's advice to the extent of employing someone in Marseille to raise and send them olive trees, and that 40 olive tree cuttings had arrived from there at Baltimore, as well as a box of seeds. The former were to be grafted on stock raised from the seed. Another cargo was on its way from Bordeaux. A year later there were in Charleston 100 olive trees which had resulted from Jefferson's instrumentality, and another 100 had arrived in Philadelphia from Marseille, which also he was sending to Charleston.

It is regrettable, in view of all his good intentions, that Jefferson's devotion to introducing olive trees into America was not at all so successful as was his promotion of rice. This we learn from a letter of his in 1813 in which he bemoaned the fact that 25 years had elapsed since he sent two shipments of about 500 plants from Aix, the finest olives in the world, and that if any of them still existed it was merely as curiosities in the gardens of some Southern fellow citizens. Not a single orchard of them had been planted.

INTRODUCTION OF AGRICULTURAL CROPS FROM AMERICA INTO EUROPE

Jefferson's interest in the introduction of food plants was not limited to bringing such sources to America. He saw also the possibility of the acquisition by Europe of valuable plants from America, and various passages in his correspondence testify to this concern. On one occasion, for instance, when a French author sent him a treatise on the culture of sugar cane and cotton in France, Jefferson replied:

"The introduction of new cultures, and especially of objects of leading importance to our comfort, is certainly worthy the attention of every government, and nothing short of actual experiment should discourage an essay of which any hope can be entertained. Till that is made, the result is open to conjecture; and I should certainly conjecture that the sugar cane could never become an article of profitable culture in France. We have within the ancient limits of the United States, a great extent of country which brings the orange to advantage, but not a foot in which the sugar cane can be matured. France, within its former limits, has but two small spots, (Olioules and Hières) which brings the orange in open air, and *a fortiori*, therefore, none proper for the cane. I should think the sugar maple more worthy of experiment. There is no part of France of which the climate would not admit this tree. I have never seen a reason why every farmer should not have a sugar orchard, as well as an apple orchard. The supply of sugar for his family would require as little ground, and the process of making it as easy as that of cider. Mr. Micheaux, your botanist here, could send you plants as well as seeds, in any quantity from the United States. I have no doubt the cotton plant will succeed in some of the southern parts of France. Whether its culture will be as advantageous as those they are now engaged in remains to be tried."

After some remarks upon the economics of wine production in America, Jefferson continued:

"In general, it is a truth that if every nation will employ itself in what it is fittest to produce, a greater quantity will be raised of the things contributing to human happiness, than if every nation attempts to raise everything it wants within itself. The limits within which the cotton plant is worth cultivating in the United States, are the Rappahannock river to the north, and the first mountains to the west. And even from the Rappahannock to the Roanoke, we only cultivate for family use, as it cannot there be afforded at market in competition with that of the more Southern region. The Mississippi country, also within the same latitudes, admits the culture of cotton."[65]

On several other occasions, too, Jefferson was instrumental in at least attempting to get American plants into France. We do not know whether he was always successful, however, for his correspondence does not tell, and hostilities between France and England at the time made shipping very precarious. While residing in Paris, for instance, he sent for some

"seeds of the Dionaea Muscipula, or Venus fly-trap, called also with you, I believe, the Sensitive Plant,"[66]

and at another time he asked someone to procure for him two or three hundred "paccan" nuts from the "western country," suggesting that they be obtained at Pittsburgh and giving directions for sending them in a box of sand.[67] His correspondent could not have been well acquainted with what Jefferson wanted, for later the same year we find him explaining that

[65] Letter to M. Lasteyrie, July 15, 1808 (13, XII, *90*).
[66] Letter to Mr. Hawkins, August 13, 1786 (13, V, *390*).
[67] Letter to Mr. Hopkinson, January 3, 1786 (13, V, *243*).

"The paccan-nut is, as you conjecture, the Illinois nut. The former is the vulgar name south of the Potomac, as also with the Indians and Spaniards, and enters also into the Botanical name which is Juglans Paccan."[68]

It would seem safe to assume that Jefferson made similar efforts to fill the request of another correspondent who had sent him from London the kinds of peas and vetch cultivated in England and which Jefferson wanted for his own farm. This writer asked that he be sent seed of the Buffalo clover, *Trifolium reflexum*, which was said to abound west of the mountains; also of some shrub which he could not name but which the famous John Bartram had mentioned to him as growing wild only in Jefferson's neighborhood, the fruit of which produced a pure oil.[69]

Elsewhere Jefferson tells of having furnished cotton seed from our southern States to the Agricultural Society of Paris upon their request for experimental purposes, and two or three barrels of Virginia May wheat to the London Board of Agriculture. Washington, he relates, received seed of perennial succory from the same French society, and he himself received from another member of it, seed of the famous Swedish turnip. Jefferson told of these exchanges in illustrating how well agricultural societies functioned with mutual respect despite the wars between their respective countries.[70]

International trade in plant products also received consideration. In discussing such commerce with Portugal, Jefferson expressed the opinion to John Adams that flour could be sold to that country for less than wheat because in shipping the latter, the bran, which did not pay its own freight, also had to be carried, and much was lost in transit because of weevils and heat in the holds of vessels. With further reference to trade in plant products with Portugal, he continued:

"Coffee. Can they not furnish us with this article from Brazil?

Sugar. The Brazil sugars are esteemed, with us, more than any other.

Chocolate. This article, when ready made, as also the cocoa, becomes so soon rancid, and the difficulties of getting in fresh have been so great in America, that its use has spread but little. The way to increase its consumption would be, to permit it to be brought to us immediately from the country of its growth. By getting it good in quality, and cheap in price, the superiority of the article, both for health and nourishment, will soon give it the same preference over tea and coffee in America, which it has in Spain, where they can get it by a single voyage, of course, while it is sweet. The use of the sugars, coffee, and cotton of Brazil, would also be much extended by a similar indulgence.

Ginger and spices from the Brazils, if they had the advantage of a direct transportation, might take the place of the same articles from the East Indies.

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[68] Letter to Mr. Hopkinson, December 23, 1786 (13, VI, *21*).

[69] Letter from Wm. Strickland, May 28, 1796 (15, *64*).

[70] Letter to John Hollins, February 19, 1809 (13, XII, *252*).

Ginseng. We can furnish them with enough to supply their whole demand for the East Indies."[71]

RESUMÉ

In any attempt to evaluate Jefferson's position in the history of American agriculture, one must take into consideration the pioneering aspects of his husbandry and their influence on his contemporaries, rather than look for any outstanding yields in the crops which he produced. He was among the first in the New World to initiate the elevation of farming to a science, to experiment with new crops and new techniques, and to keep records of his activities. Rotation of crops as a means of preserving soil fertility was scarcely known in America before he and a few other enterprising farmers of the day adopted it as a fundamental element in their husbandry. It is because of these innovations as well as others, not at all discussed in this study, such as his introduction of Merino sheep and his construction of a prize-winning mold-board, that among the praises written of him in his relation to agriculture, we find that "he did more for its promotion than any other statesman that ever lived, and deserves to be the perpetual Emeritus President of the Patrons of Husbandry," and that if he "had done nothing else save to aid man's knowledge of agriculture, he would have been a benefactor."

(The second and third parts of this study as well as the bibliography will appear in later issues of the BULLETIN.)

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NEW YORK

[71] Letter to John Adams, November 27, 1785 (13, V, 222).

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THE MORPHOLOGY OF SPHAEROSTILBE AURANTIICOLA (B. & BR.) PETCH[1, 2, 3]

E. S. LUTTRELL

Sphaerostilbe aurantiicola belongs among the Hypocreales. It was described as *Nectria aurantiicola* in 1873 by Berkeley and Broome from material collected in Ceylon on scale insects parasitizing orange twigs. In 1921 Petch (22) transferred it to the genus *Sphaerostilbe*. Although the name *Nectria aurantiicola* is antedated by *Sphaerostilbe coccophila*, which was applied to the perithecial stage by the Tulasnes in 1861, the latter name was discarded by Petch. The Tulasnes had based their description upon perithecial material from Italy and connected it with the conidial form *Microcera coccophila* which Desmazières had described in 1848 from a collection on scale insects in France. Petch found, however, that perithecia were present in the specimens upon which Desmazières had based *Microcera coccophila* and that they belonged to *Sphaerostilbe flammea* Tul. *Sphaerostilbe coccophila* was, therefore, a composite species consisting of the conidial stage of one species and the perithecial stage of another. In order to avoid confusion Petch selected *Sphaerostilbe aurantiicola* as the correct name. This is, perhaps, a doubtful basis for the rejection of the name first applied to the perithecial stage of the fungus, but since Petch's usage appears to have gained acceptance, it is employed herein.

Sphaerostilbe aurantiicola occurs throughout the world as a parasite upon various species of scale insects. Petch (22) examined collections of it from France, Italy, Madagascar, Ceylon, India, Formosa, Japan, Dominica, and the United States. In Florida alone it has been reported (Watson and Berger 28) upon thirteen species of scale insects.

It is of importance in the biological control of scale insects—especially the San Jose scale—on fruit trees in Florida. Its importance in this respect was first recognized by Rolfs (23) in 1897. In certain Florida orchards on some trees which previously had been severely infested with San Jose

[1] Paper No. 124, Journal Series, Georgia Agricultural Experiment Station.

[2] Specimens of the fungus, collection No. 5002, and slides representative of the series upon which this study was based have been deposited in the Farlow Herbarium, Harvard University. A culture, No. 76, has been deposited in the American Type Culture Collection, Georgetown University School of Medicine.

[3] I am indebted to Dr. B. B. Higgins, Georgia Agricultural Experiment Station, Dr. B. O. Dodge, New York Botanical Garden, and Dr. F. A. Wolf, Duke University, for examining the preparations and criticizing the manuscript and to Mr. J. Gordon Futral of this Station for his advice and assistance in taking the photomicrographs reproduced in figs. 1–13.

scale, he found that the scale had been almost entirely eliminated by *Sphaerostilbe aurantiicola*. He recommended the introduction of the fungus into orchards in which it was not already present by tying branches bearing diseased scales to the infested trees or by spraying the trees with a suspension of conidia from nature or from cultures. This method of natural control of the San Jose scale has been successful in Florida because climatic conditions there favor the development of the fungus (Watson and Berger 28); elsewhere it has not been of much consequence. Smith (24) obtained the fungus from Rolfs and introduced it into New Jersey where it spread but proved to be a failure in control of the scale. Earle (8) reported that in Alabama, because of the dry climate, the fungus was not active enough to control scale efficiently. Forbes (10) early stated that it gave promise of being effective in the control of the San Jose scale in Illinois, but in later reports he made no mention of it.

Although no attempt has been made to utilize the fungus in the control of scale insects in Georgia, in the vicinity of the Georgia Agricultural Experiment Station it is commonly present on obscure scale [*Chrysomphalus obscurus* (Comst.)] on water oak (*Quercus nigra* L.). Since it was available in all stages of development, a special morphological study of it was made. The present report is concerned primarily with the development of the perithecium of *Sphaerostilbe aurantiicola* and a comparative review of the published accounts of perithecial development in other species of Hypocreales. Accounts of the taxonomy, gross morphology, and biology of this fungus may be found in papers by Petch (22) and Rolfs (23).

METHODS

Infected scales were stripped from the bark or else a thin layer of bark bearing the scale was shaved from the infested branch. The fixative employed was Formalin-proprionic-alcohol solution (70 % ethyl alcohol, 90 parts; proprionic acid, 5 parts; Formalin, 5 parts). The fixed material was washed in 70 per cent alcohol, passed through a graduated series of tertiary butyl alcohols, and embeded in 60 degree Tissuemat. Serial sections were cut at a thickness of 8 microns. The sections were treated with 1 per cent chromic acid, stained in a fresh solution of Haidenhain's haematoxylin, differentiated with a saturated solution of picric acid, and mounted in balsam. Some were counter-stained with fast green dissolved in clove oil, but these were not superior to sections stained with haematoxylin only. In addition, freehand sections and smears of fresh and fixed material mounted in water or in lactophenol containing 1 per cent cotton blue were studied. Drawings were made with the aid of an Abbe camera lucida. Photomicrographs were taken with a Leitz Makam photomicrographic apparatus on medium lantern slide plates.

THE CONIDIAL STAGE

The first macroscopic sign of infection of the scale insect is the appearance of conidial fructifications. These are abundant throughout the year but are most conspicuous during periods of rainy weather in spring or in late fall. The fructifications are 0.5–1.5 mm. high. They may be stilboid in form, consisting of a short, whitish stalk surmounted by a broader, globular, orange conidial head. Generally, however, the stalk is poorly developed, the head being almost sessile (fig. 2). The commonest form is that illustrated in figure 1. The stalk is very short and broad, and the fructification is pulvinate rather than stilboid. The heads vary from 299–1035 μ in height and from 390–1300 μ in diameter, while the stalks vary from 130–650 μ in length and from 234–780 μ in diameter. A whitish sheath, which is more conspicuous in dry specimens, surrounds the stalk and envelops the basal part of the conidial head. When dry the surface of the head, especially in older fructifications, is often flat or slightly cupulate, and the sheath may then appear as a fringe around the margin of the discoid head. When moistened, the head swells, becomes convex, and protrudes from the sheath. According to Petch (22), the sessile or pulvinate form of fructification is characteristic of the fungus in temperate regions. In the tropics they are larger, better developed, and almost always stilboid. From one to sixteen conidial heads may develop on a single scale; usually from two to eight are produced. They project from the margin of the scale, forming a ring partially or completely surrounding it. The bases of the stalks are sometimes united by a stromal band that barely protrudes from beneath the scale. The conidial head may also push through the surface of the scale at any point.

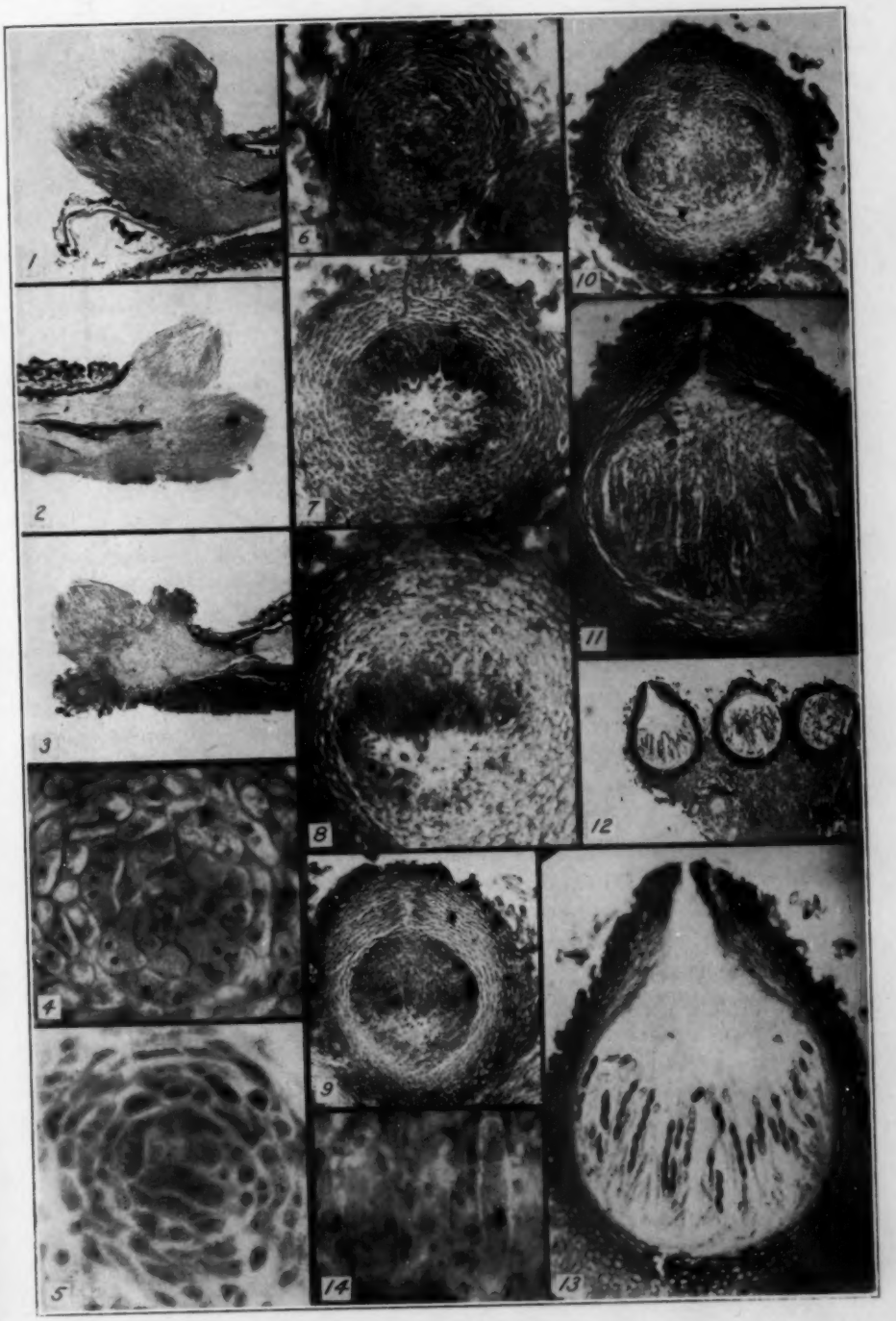
Sections of infected scales show that when the conidial heads appear the fungus has completely destroyed the body of the scale and filled the space between the resistant shield of the scale and the bark with a plectenchymatous stroma (figs. 1, 3). The fungus does not penetrate the bark but attacks only the scale. Its stroma is composed of hyphae of varying diameters which are irregularly and intricately interwoven. The hyphal cells are cylindrical, their cytoplasm is vacuolate and granular, and each contains a single conspicuous nucleus. The conidial fructifications are initiated as protuberances of this stroma. Toward the apex of the protuberance the hyphae become arranged paralled to its axis and separate above to form a fascicle of slender branching conidiophores which are 2.5–5.0 μ in diameter (fig. 2). In the hyphae of the stalk and in the conidiophores the cytoplasm is denser and the nuclei are more deeply staining than in the remainder of the stroma. In the basal part of the head the conidiophores are often joined to one another by ladder-like connections. Conidia are abstricted singly from the tips of conidiophores. In the formation of a conidium the tip of the terminal cell of a conidiophore elongates and increases in diameter. Its

nucleus divides, one daughter nucleus remaining in the base, the other migrating into the elongating tip. A constriction appears at the base of the enlarged terminal portion, and finally a cross wall is laid down in the constriction, cutting off the uninucleate, fusiform young conidium (fig. 38) which has now reached almost its mature dimensions. By division of the primary nucleus the conidium becomes binucleate. Further nuclear divisions and the formation of cross walls were not observed, but the conidium ultimately is divided into 4–11 uninucleate cells. The appearance of conidia divided by four transverse walls into cells much longer than those of mature conidia indicates that cross walls are formed immediately after each nuclear division. Masses of conidia are thus formed in the apex of the head. The mature conidia are 3–10-septate (the majority 5–8-septate) and measure 64–100 × 5.6–8.4 μ. They are hyaline, fusiform, straight or more often curved, and acute at the tips. The proximal end is generally somewhat falcate; the distal end is almost straight (fig. 38).

The peripheral layer of hyphae in the stalk remains sterile and extends upward as a sheath surrounding the fascicle of conidiophores. In the apical portion the sheath is sometimes divided into triangular teeth appressed to the sides of the conidial head. More often, however, the teeth are not distinct, and the sheath terminates in an irregular fringe of hyphae. This observation is in agreement with Petch's (22) description. He found in

Explanation of figures 1–14

All figures photomicrographs. FIG. 1. Conidial fructification of *Sphaerostilbe aurantiicola* on *Chrysomphalus obscurus*. × 40. FIG. 2 Young conidial heads growing out from beneath the margin of the scale. × 40. FIG. 3. A conidial head with a group of perithecial initials in various stages of development lying in the stroma immediately beneath. The central cavity has been developed in the young perithecium on the lower right. × 40. FIG. 4. An ascogonium embedded in the stroma. × 1000. FIG. 5. An ascogonium surrounded by concentric layers of vegetative hyphae which will form the perithecial wall. × 1000. FIG. 6. Young perithecium. A wall formed by vegetative hyphae encloses the ascogonium. × 400. FIG. 7. Perithecium showing the origin of the vertical hyphae from the inner portion of the perithecial wall. The basal part of the perithecial cavity is occupied by a mass of ascogonial cells which are being emptied of their contents. × 400. FIG. 8. Perithecium in which the vertical hyphae have formed a palisade of parallel hyphae growing downward from the apical portion of the wall. A few 2–4-nucleate cells are scattered among the empty ascogonial cells. × 400. FIG. 9. Perithecium in which the vertical hyphae have almost filled the perithecial cavity. The remains of the emptied ascogonial cells are being crushed at the base of the perithecium. The ostiole is being initiated in the apical region of the wall. × 160. FIG. 10. Perithecium just prior to the formation of asci. The vertical hyphae have increased in diameter to fill the perithecial cavity and their tips have pushed into the base of the perithecium. Formation of the ostiole is in progress. × 160. FIG. 11. Perithecium with young, uninucleate asci growing upward among the vertical hyphae. The ostiole is almost completely formed. × 160. FIG. 12. Group of mature perithecia partially embedded in the stroma. × 40. FIG. 13. Mature perithecium with asci in all stages of development. The vertical hyphae are disintegrating. The ostiole is completely formed. × 160. FIG. 14. Portion of the hymenium showing a uninucleate ascus among the swollen vertical hyphae. The binucleate cell at the base of the ascus is proliferating to form a second ascus by means of a crosier. × 1000.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specimens from tropical regions that the teeth of the sheath were well defined but that they tended to separate into their constituent hyphae in specimens from the temperate zone.

DEVELOPMENT OF THE PERITHECIUM

Perithecia of *Sphaerostilbe aurantiicola* may develop at any time during the year when sufficient moisture is available. Perithecia initiated in the spring become mature during late spring or early summer. There is little further development during the dry summer months, but in the fall activity is usually resumed. As a result of rainy weather during the fall, perithecia were abundant in November and December of 1942. At this time perithecia in all stages of development were present on the infested branches. Indeed, a variety of stages could often be found in sections of a single infected scale. Most of the perithecia were washed away during the winter, but a few mature perithecia were still present the following spring. During the fall of 1943, however, no perithecia developed. This was probably because of long periods of dry weather during that season.

The first indication of perithecial development is the formation of ascogonia within the stroma. Ascogonia are produced in large numbers at the base of the conidiophores, in the periphery of the stalk below the conidiophores, and just below the surface of the stroma at the margin of the scale. They are just beginning to form at the stage of development illustrated in figure 1. A fully developed ascogonium is an intricate, compact coil of enlarged multinucleate cells whose protoplasm is denser and more deeply-staining than that of the surrounding hyphae of the stroma (fig. 4). Each ascogonial cell contains from two to as many as twelve nuclei (fig. 34). Furthermore, the ascogonial nuclei are larger than those of the vegetative cells. The youngest ascogonium observed was a recurved hypha of several slightly enlarged, rather deeply staining, 1–2-nucleate cells, tapering at the base into an ordinary vegetative hypha (fig. 35). Apparently the ascogonium originates from a branch of a vegetative hypha. In its formation the hypha becomes recurved and coils about itself, its cells enlarge, the protoplasm becomes denser, and each cell becomes multinucleate by free nuclear division of the single original nucleus. Neither trichogynes nor spermatia or any sort of antheridial structures with which copulation could take place were observed. There was no evidence of fusions between ascogonia or between cells of a single ascogonium. The nuclei usually do not appear to be arranged in pairs but are irregularly distributed in the ascogonial cells.

The surrounding hyphae of the stroma now produce branches which coil about the ascogonium (fig. 5) and soon enclose it within a spherical envelope composed of several layers of concentrically arranged hyphae (fig. 6). This envelope increases in thickness and develops into the wall of the young

perithecium. At this stage the perithecia begin to protrude from the stroma (fig. 3), and are visible under the hand lens as tiny pimples clustered upon its surface. By continued growth of the hyphae constituting the wall a schizogenous cavity is created in the center of the young perithecium. This cavity becomes filled as it develops, however, for the hyphae making up the inner layers of the wall give off branches which grow inward, their free tips directed toward the center of the perithecium (fig. 7). A difference in rates of growth of these hyphae is soon evident. Those arising from the base and sides of the perithecium grow relatively little, producing a small mass of plectenchymatous tissue in the base of the perithecium below the ascogonium, while those arising from the apical portion of the wall grow rapidly, keeping pace with the expansion of the wall and filling the perithecium with a palisade of simple hyphae arranged parallel to its longitudinal axis. Their attachment to the apical region of the wall is always clearly evident. Their free tips are directed toward the base of the perithecium and press downward against the ascogonium (figs. 8, 36). The terminal cells of these vertical hyphae remain densely filled with protoplasm, while the proximal cells lying toward the apex of the perithecium become vacuolate. The cells are uni- or binucleate (fig. 36).

Meanwhile the ascogonial cells have continued to enlarge. Their protoplasm moves to one side of the cell (fig. 36), and gradually they become emptied, appearing as a hyaline mass of large, thin-walled cells occupying the center of the perithecium. There is little indication that the protoplasm of the ascogonial cells is disintegrating; instead, it appears to be moving out of the cells. On the other hand, there was no clear evidence of the production of branches from the ascogonial cells into which their protoplasm might migrate. Because of the compact arrangement of the ascogonial cells, any branches arising from them would necessarily be extremely tortuous, and it is unlikely that the course of a branch could be followed in sectioned material. Occasionally an ascogonial cell with a protuberance which might represent the basal part of a branch the distal part of which had been lost in sectioning is found. Also, 2–4-nucleate cells provided with a dense cytoplasm appear among the empty ascogonial cells (fig. 36). It seems probable that they are portions of ascogenous hyphae arising from the ascogonium. This has not been demonstrated conclusively, however, and it is possible that the binucleate cells which appear among the ascogonial cells are derived from the deeply staining, often binucleate terminal cells of vertical hyphae which have pushed in to the ascogonial coil. Although the ascogonial cells are long persistent, they are ultimately crushed by the downward growth of the vertical hyphae (figs. 9, 10).

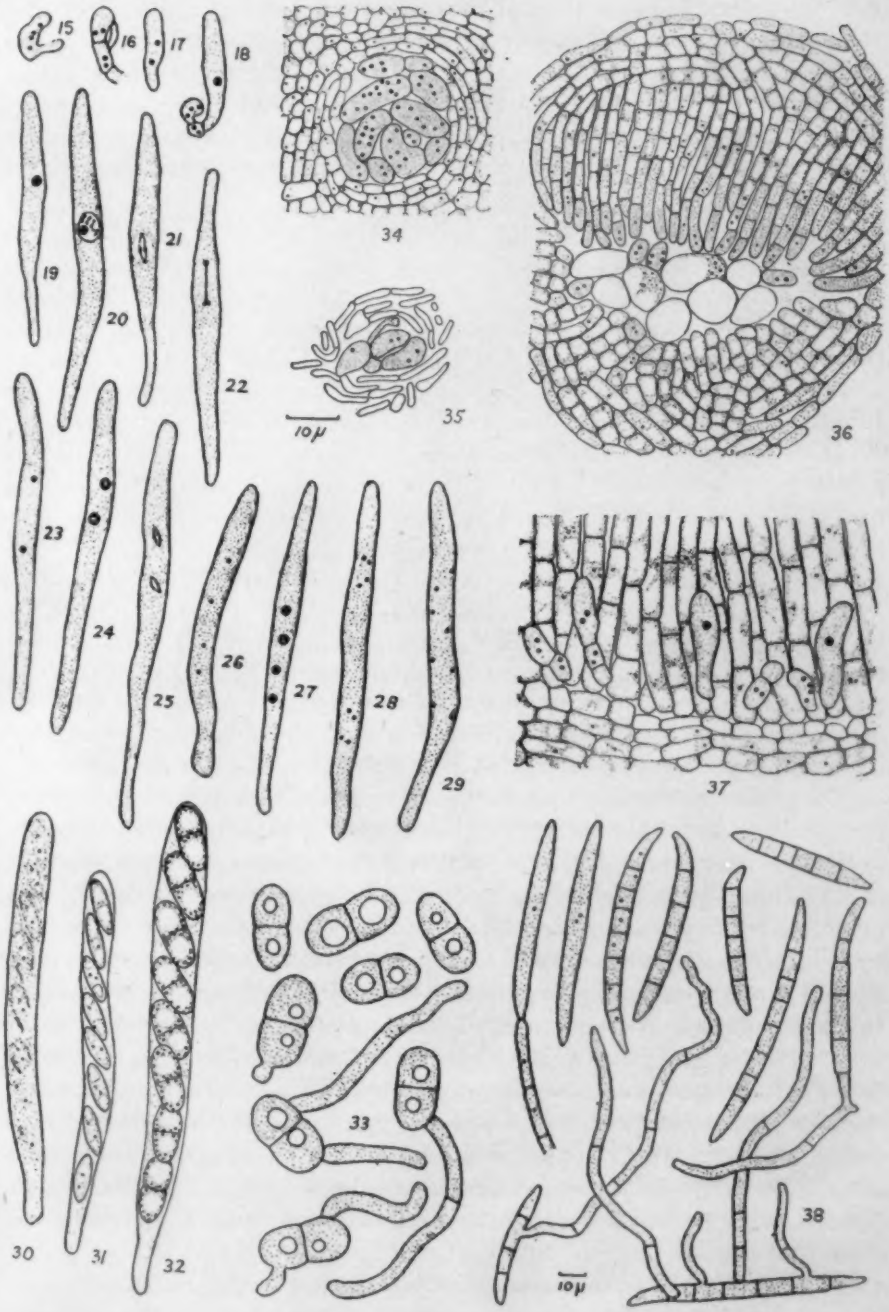
The perithecial wall is now thickened and differentiated into two layers: an inner portion composed of 6–12 layers of hyaline cells which are com-

pressed and flattened by the pressure resulting from the growth of the vertical hyphae within the perithecium, and an outer portion of large, thick-walled, pigmented cells. About the time that the ascogonia disappear the ostiole begins to develop. In the thicker apical region branches of hyphae composing the inner portion of the wall turn upward and begin to grow more rapidly (fig. 9). Their upward growth produces a papilla, and by their pressure against one another the hyphae in the core of the papilla are separated, forming an ostiole lined with free hyphal ends (figs. 10, 11).

While the ostiole is forming, the vertical hyphae within the perithecium continue growing until they extend to the bottom of the perithecium. Their tips press into the plectenchymatous tissue lining the basal portion of the perithecial wall so that they are attached both above and below (fig. 10). They now swell, and the protoplasm of their cells becomes thin and vacuolate. Each cell contains one or several nuclei (fig. 37). In the plectenchyma lining the base of the perithecium among the tips of the vertical hyphae are binucleate cells, appearing singly or in chains of two or three cells (fig. 37). These presumably are the ascogenous cells mentioned above as probably being derived from the ascogonium. Whatever their origin, they now proceed to form asci by means of croziers. As the asci develop the perithecium continues to enlarge. The vertical hyphae separate and gradually disintegrate, leaving a cavity above the asci (figs. 11, 13). Even now their attachment to the apical portion of the wall is still clearly evident. Although they resemble paraphyses, in view of their origin, it is clear that they are not true paraphyses. They constitute a nurse tissue within which the asci develop. Paraphyses are never formed in *Sphaerostilbe aurantiicola*. As the asci ma-

Explanation of figures 15–38

Camera lucida drawings. Fig. 38 to the scale shown in the same figure, all others to the scale shown in fig. 35. FIGS. 15–32. Development of the ascus. FIG. 15. Initiation of crosier. FIG. 16. Crosier. The ultimate cell of the crosier has fused with, and its nucleus has passed into, the basal cell. FIG. 17. Young ascus prior to fusion of the two nuclei. FIG. 18. Young ascus in which the two nuclei have fused. The binucleate basal cell is proliferating to form a second crosier. FIG. 19. Young ascus with enlarged fusion nucleus. FIG. 20. Early prophase of 1st division. FIG. 22. Late anaphase of 1st division. FIG. 23. 2-nucleate ascus. FIG. 24. Prophase of 2nd division. FIG. 25. Early anaphase of 2nd division. FIG. 26. 4-nucleate ascus. FIG. 27. Prophase of 3rd division. FIG. 28. Telophase of 3rd division. FIG. 29. Eight-nucleate ascus. FIG. 30. Ascus in which cleavage furrows are cutting out eight ascospores. Each ascospore nucleus has already divided to form two daughter nuclei. FIG. 31. Ascus with young unicellular spores. FIG. 32. Ascus with eight almost mature two-celled ascospores. FIG. 33. Mature ascospores after discharge from the ascus and stages in their germination. FIG. 34. Ascogonium embedded in the stroma. FIG. 35. Young ascogonium. FIG. 36. Section of young perithecium showing the palisade of vertical hyphae growing downward into the perithecial cavity. 2- and 4-nucleate cells appear among the empty ascogonial cells. FIG. 37. Section of the base of a perithecium in which asci are forming among the swollen vertical hyphae. FIG. 38. Origin of conidium from tip of conidiophore, mature conidia, and germination of conidia.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ture the inner hyaline portion of the wall is crushed and flattened against the darkened outer portion, leaving a relatively thinner wall enclosing an enlarged central cavity. The mature asci occupy the lower two-thirds of this cavity (fig. 13). They are 112–154 μ long and 14–16.8 μ in diameter. Each contains eight hyaline, elliptical to oblong, two-celled ascospores measuring 12.5–18.7 × 7.2–10 μ. The ascospores are uniseriately arranged within the asci.

Mature perithecia are roughly spherical to ovate with a slight papilla penetrated by a periphysate ostiole at the apex and are 273–377 μ in diameter. They are pale-rose-colored when dry, but they become bright red when moistened. The perithecia are usually clustered upon the stroma in which their basal portions are embedded (fig. 12), and they often are grouped around the old conidial fructifications. When only a few perithecia are formed, they may appear scattered over the surface of the scanty stroma.

Each perithecium arises from a single ascogonium. The ascogonia are numerous, however, and not all of them develop into perithecia. Sections have been examined which showed an ascogonium being enclosed by the wall of another perithecial initial in a more advanced stage of development. The included ascogonium was disintegrating. Another abnormality observed was produced from two perithecia developing in proximity. Their adjacent walls had fused and become compressed and partially disintegrated. Although the two perithecia possessed one common perithecial cavity, each formed its separate ostiole.

CYTOLOGY OF THE ASCUS

The asci of *Sphaerostilbe aurantiicola* arise from binucleate cells in the plectenchyma lining the base of the perithecium. Although slightly bowed 4-nucleate cells whose appearance suggested that of croziers were observed arising from the ascogenous cells (fig. 37), no structures which could be identified positively as croziers were found in the stained sections. Recourse was, therefore, had to smears and mounts of perithecia teased apart. In such mounts it was occasionally possible to demonstrate the presence of croziers. In the production of an ascus a binucleate ascogenous cell elongates and becomes bowed while the two nuclei divide to form four (fig. 15). This four-nucleate cell is now divided by two cross walls into a basal uninucleate cell, an apical uninucleate cell, and a median binucleate cell. The apical cell recurves and fuses with the basal cell, and its nucleus passes into the basal cell (fig. 16). The median cell elongates to form the young binucleate ascus (fig. 17), while the now binucleate basal cell may proliferate to form a second ascus (figs. 14, 18).

The two nuclei in the young ascus fuse to form a single larger fusion nucleus. Initially the fusion nucleus is homogeneous (figs. 18, 19), but as it

enlarges its structural detail becomes evident (fig. 20). The nuclear membrane, a single conspicuous nucleolus, and several chromatin threads may be distinguished. No centrosomes were observed in the interphase nuclei nor during the prophase. The next stage observed was a metaphase of the first division (fig. 21). The spindle lay in a clear area in the cytoplasm, oriented parallel to the longitudinal axis of the ascus and was no longer than the diameter of the original nucleus. The nucleolus had disappeared. Tiny black masses observed at either end of the spindle probably represent centrosomes. At the equator of the spindle were two chromatic masses each of which possibly comprised two chromosomes since, as will be noted later, two such masses were observed migrating to each pole during the anaphase of the second division. It is probable that the chromosome number is two although the smallness of the division figures makes certainty of this impossible. At any rate, the chromatin masses move to the poles while the spindle elongates and appears as a dark strand between the two masses (fig. 22). From these two chromatin masses two daughter nuclei are reorganized. The interphase nuclei are small and homogeneous (fig. 23). As they prepare for the second division they enlarge, although even so their diameters are less than half that of the primary fusion nucleus. In the prophase the nuclear membrane, chromatin threads and nucleolus are once more discernible (fig. 24). The next stage observed was an anaphase of the second division showing two spindles slightly oblique in orientation to the ascus. In each figure there were two chromosomes passing to either pole (fig. 25). The four nuclei reorganized from the second division were also small and homogeneous (fig. 26). As they entered the prophase of the third division they enlarged slightly and their internal structure became apparent (fig. 27). The only stage of the third division observed was a telophase (fig. 28) in which the position of the eight chromatin masses indicated that the orientation of the spindles had been oblique.

After the third division of the fusion nucleus, eight homogeneous daughter nuclei are reorganized (fig. 29). Cleavage furrows then cut out an elliptical ascospore around each nucleus. There was no evidence that astral rays function in the delimitation of the ascospores. Each nucleus divides immediately, often before the outlines of the ascospore are clearly visible, to form the two nuclei of the ultimately two-celled ascospore (figs. 30, 31). An oil globule now forms at each end of the ascospore. The two nuclei migrate toward opposite ends of the ascospore, and a cross wall is laid down, dividing the spore into two cells. The oil vacuoles enlarge, and the cytoplasm becomes granular and filled with chromatic masses so that the nucleus is obscured (fig. 32). The interval between the uninucleate ascus and the formation of spores must be short, as it was difficult to find intermediate stages.

SPORE GERMINATION AND GROWTH IN CULTURE

Cultures of *Sphaerostilbe aurantiicola* were obtained from conidia by streaking a conidial suspension upon agar plates and from ascospores by suspending mature perithecia from the top of a Petri dish so that the spores were discharged upon the agar below. Both types of spores germinated overnight although the conidia germinated more rapidly than did the ascospores. Any of the three to twelve cells of the conidium may produce a single germ tube (fig. 38). Usually, several germ tubes originate from each conidium. Often certain cells in the conidium, either terminal or intercalary, appeared narrower and less swollen than the remainder of the cells. This apparently is of no significance, since the narrow cells produced germ tubes as readily as the swollen cells. Conidia produced in masses in cultures in which the nutritive medium is already covered by mycelium may germinate to form secondary conidia similar to the primary conidia. Secondary conidia are probably produced similarly in nature by conidia that fall upon substrates unfavorable for their growth. In germination either cell of the ascospore may produce a single germ tube. One or two germ tubes arise from each ascospore (fig. 33).

The fungus was cultured on potato dextrose agar, malt agar, and on acidulated bread, as suggested by Rolfs (23). It grew equally well on all three media. The average rate of growth at room temperature as determined from measurements of fifty-three colonies in three series of experiments conducted at different times was 0.782 mm. per day. The differences in rates of growth of colonies kept in total darkness and those given various daily exposures to light from five minutes to a full day were extremely slight and variable. It is concluded that light has no effect upon rate of growth in culture.

Although light has no influence upon rate of growth, it does have a pronounced effect upon character of the mycelium produced. In cultures maintained in total darkness the mycelium is thick and fluffy, forming sharply delimited pulvinate colonies, while in those exposed to light it grows closely appressed. This difference in type of growth results in distinct zonation in colonies kept in the laboratory where they were exposed to daily alternations of light and darkness. Colonies kept in total darkness and removed for measurement every two days also exhibited zonation, although there were only half the number of concentric rings in these colonies as in those exposed to natural illumination. The brief exposure to light of not more than ten minutes every forty-eight hours necessary for making measurements was sufficient to induce zonation.

Light modifies also the production of conidia in culture. Colonies kept in total darkness for one month produced no conidia, while those exposed to light developed conidia within eight days. Experiments in which series of

cultures of five each were kept in total darkness or exposed to the light from a north window of the laboratory for periods of five, fifteen, thirty, and sixty minutes daily showed that exposure to light for as short a period as five minutes daily resulted in the formation of conidia. The condidia are formed in orange masses lying in concentric rings corresponding to the zonation of the mycelium. They are identical with those formed in nature, and no other spore form is produced. Penicillium-like spores described by Rolfs (23) have not appeared in my cultures.

A few scattered perithecia formed in old cultures on potato dextrose agar, but these never produced ascospores.

PERITHECIAL DEVELOPMENT IN THE HYPOCREALES

Archicarps. Initiation of perithecia without the intervention of archicarps has been reported for only two species of Hypocreales, *Nectria Ipomoeae* Halst. [*Hypomyces Ipomoeae* (Halst.) Wr.] and *Nectria galligena* Bres. Cook (5) was unable to find them at any stage in the development of perithecia of *Nectria Ipomoeae*. According to Cayley (4), the perithecium of *Nectria galligena* originates as a globular mass of vegetative hyphae which becomes differentiated into a perithecial wall and a central tissue of thin-walled cells. Later an ascogonium develops within the young perithecium. It seems probable that in these two species the early stages of ascogonial formation have been overlooked, for in all other species the perithecium is always initiated by an archicarp. Furthermore, there is considerable uniformity in its structure in the various species. As in *Sphaerostilbe aurantiicola*, it is usually in the form of an ascogonium composed of a coil of enlarged binucleate or multinucleate cells differentiated from the vegetative cells by their larger size, their more deeply staining protoplasm, and the number and size of their nuclei. Such ascogonia have been described in *Nectria Ribis* (Tode) Rabenh. (Vincens 27), *Hypocrea gelatinosa* (Tode) Fr. (Vincens 27), *Thyronectria denigrata* (Wint.) Seaver (Lieneman 16), *Peckiella lateritia* (Fr.) Maire (Moreau 20), *Cordyceps agariciformia* (Bolt.) Seaver (Jenkins 14), *Cordyceps militaris* (L.) Link (Varitchak 25, 26), *Claviceps microcephala* (Wallr.) Tul. (Vincens 27), *Claviceps purpurea* Tul. (Killian 15), and *Epichloe Bambusae* Pat. (Gaümann 12). The ascogonium of *Polystigma rubrum* DC. (Nienburg 21) is similar except that it terminates in an elongated trichogyne.

Origin and Sexuality of Archicarps. In all species studied, whether their mature perithecia are immersed within a well-developed stroma as in *Hypocrea, Claviceps,* and *Epichloe* or merely clustered upon the surface of a stroma as in *Sphaerostilbe* and *Thyronectria,* the ascogonia are formed within a stroma. Formation of the ascogonium generally seems to be similar

to the process described in *Sphaerostilbe aurantiicola*. A branch of a vegetative hypha enlarges, becomes more deeply staining, and coils. The cells become multinucleate by free nuclear division. Generally there are no fusions between ascogonia, between cells of a single ascogonium, or between ascogonia and other reproductive structures. *Polystigma rubrum* (Nienburg 21) and *Epichloe Bambusae* (Gaümann 12) are to be noted as exceptions in which fusions between cells of the ascogonium have been reported. Fusion of the ascogonium with an antheridium has been described in *Claviceps purpurea* (Killian 15), *Claviceps microcephala*, and *Hypocrea gelatinosa* (Vincens 27). Although *Polystigma rubrum* produces spermatia coincidentally with the ascogonia, the spermatia at present are considered to be nonfunctional. Early observers (Fisch 9, Frank 11) believed the spermatia and trichogynes to be functional, but later workers have disagreed. Blackman and Welsford (2) were unable even to trace the trichogyne to the surface of the stroma; and while Nienburg (21) found that the tip of the trichogyne projected from the surface of the stroma, he also considered it to be nonfunctional. Lack of accord in the observations of different mycologists upon the same or related species shows that satisfactory cytological evidence for the functioning of supposed sexual organs is often difficult to obtain. Consequently, some doubt must exist as to the extent of the occurrence of sexual fusions in the Hypocreales.

The problem of sexuality may be more successfully attacked in heterothallic species in which the results of genetical experiments may be correlated with cytological evidence. Heterothallism has been reported in several species of Hypocreales; but, unfortunately, the morphological basis of sexuality in these species has not yet been determined. Dimock (7) described the occurrence of two mutually compatible, hermaphroditic but self-sterile strains in *Hypomyces Ipomoeae* (Halst.) Wr. When cultured from monosporous isolations, each strain produced perithecial initials, but these did not develop into mature perithecia. When opposite strains were mated, however, perithecia developed. Dimock (7) found also that he could induce formation of perithecia by placing a suspension of microconidia from one strain upon the mycelium of the opposite strain. " . . . , perithecia developed only on those portions of the colony which had actually been wetted by the microconidial suspension. When single drops of spore suspension were added, perithecia developed only within the limits of the drop." *Hypomyces roselius* (Alb. & Schw.) Tul. (Zycha 29) and *Hypomyces Solani* f. *Cucurbitae* (Hansen & Snyder 13) also have been proved to be heterothallic. Careful morphological studies of these heterothallic species will probably demonstrate the presence of functional trichogynes which fuse with either micro- or macroconidia.

Perithecial Wall. Whatever the sexual nature of the ascogonia, it is certain that they are the centers around which the perithecia develop. Only a single ascogonium may be involved in the formation of a perithecium, as in *Sphaerostilbe aurantiicola*, or as many as three distinct ascogonia may function in the formation of a single perithecium, as in *Cordeyceps agariciformia* (Jenkins 14). The ascogonia early become invested by layers of sterile hyphae which may originate from the ascogonial stalks or from branches of the surrounding vegetative hyphae. This envelope of sterile hyphae surrounding the ascogonium increases in thickness, and by growth of its constitutent hyphae it expands to form a flask-shaped wall enclosing the perithecial cavity. At the apex a papilla penetrated by a schizogenously formed ostiole lined with periphyses develops. When the perithecia remain immersed within the stroma at maturity, the perithecial walls are sometimes not well developed. Vincens (27) states that the perithecial wall of *Hypocrea gelatinosa* is thin and poorly delimited at the periphery. This is true also of species belonging to the Claviceptaceae. In the most extreme example described, *Epichloe typhina* (Vincens 27), a perithecial wall is not developed at all, the expansion of the ascogenous hyphae and asci merely creating an unwalled locule in the stroma. According to Brandriff (3), perithecial walls are lacking also in *Acrospermum compressum* Tode.

Ascogenous Hyphae. As the perithecial wall forms, the ascogonia continue their development within the perithecium. Generally, ascogenous hyphae arise as branches of the ascogonial cells. It is, however, often exceedingly difficult to trace all of the stages in this process. My observations upon *Sphaerostilbe aurantiicola* incline me to believe that the ascogenous hyphae in this species are produced from the ascogonia, although it has been impossible to demonstrate this satisfactorily. The evidence obtained might be interpreted as indicating that the ascogonia disintegrate after serving as stimulatory organs for the intiation of the perithecia and that the ascogenous hyphae arise subsequently from hyphae derived from the wall in the base of the perithecium or from the often binucleate terminal cells of the vertical hyphae. Both of these interpretations have been applied previously to various species. In *Hypocrea gelatinosa* (Vincens 27), *Peckiella lateritia* (Moreau 20), *Cordyceps agariformia* (Jenkins 14), *Cordyceps militaris* (Varitchak 25, 26), *Claviceps microcephala* (Vincens 27), *Claviceps purpurea* (Killian 15), *Epichloe typhina* (Vincens 27), and *Ephichloe Bambusae* (Gaümann 12) reports indicate that the ascogenous hyphae arise from the ascogonia or from certain cells of the ascogonia. This appears to be true also of *Nectria galligena* although Cayley (4) in an ambiguous statement indicates that the ascogenous hyphae in this species arise de novo from hyphae in the base of the perithecium. On the other hand, Vincens (27) states that

in *Nectria Ribis* the ascogonia disintegrate completely and that ascogenous hyphae arise from ordinary hyphae in the base of the perithecium. A similar process is reported by Blackman and Welsford (2) for *Polystigma rubrum*. Nienburg (21), however, in a study of the same species found that the ascogonium does not disintegrate completely but that one cell of the ascogonium continues its development and gives rise to ascogenous hyphae. Although it is possible that in some species of Hypocreales the ascogonia may no longer be functional in the production of ascogenous hyphae, nevertheless, the difficulties in tracing their development may be responsible for the conclusion that they are functionless.

Paraphyses. According to Miller's (18) definition of a perithecium, an essential characteristic is the presence of paraphyses in the centrum. This is true of *Nectria galligena* (Cayley 4) and *Hyomyces aurantiius* (Vincens 27). Paraphyses are present also in *Thyronectria denigrata* (Lieneman 16), but they are unusual in that, while they arise from the base and sides of the perithecium, they are branching anastomosing structures embedded in a gelatinous matrix. No mention of paraphyses is found in the papers of Blackman and Welsford (2) on *Polystigma rubrum* and of Moreau (20) on *Peckiella lateritia*. Paraphyses are not, however, uniformly present in the Hypocreales. Paraphyses do not occur in the perithecia of the Claviceptaceae including the species mentioned above under the genera *Cordyceps, Claviceps* and *Epichloe*. In these species the ascogenous hyphae occupy the basal portion of the perithecial cavity, and the asci grow up into the cavity as it develops. Paraphyses are lacking also in *Hypomyces rosellus* (Zycha 29). According to Cook (5), the perithecia of *Nectria Ipomoeae* are aparaphysate. The young perithecium is filled with a mass of thin-walled pseudoparenchyma. Asci originate in the base of the perithecium and push up into this pseudoparenchyma which is crushed and disintegrated as the asci mature. In *Sphaerostilbe aurantiicola* the perithecial cavity is filled by a mass of vertical hyphae originating from the ostiolar region of the perithecial wall. The resemblance of these hyphae to the vertical hyphae in the ascocarp of *Sporormia leporina* Niessl. as described by Arnold (1) is worthy of mention. The latter have been considered pseudoparaphyses by Miller (19). Since pseudo paraphyses have been reported only in species with stromatic ascocarps which presumably lack perithecial walls and since the nature of pseudoparaphyses is not yet clearly understood, it seems advisable at present to designate the palisade-like mass of vertical hyphae in the perithecium of *Sphaerostilbe aurantiicola* simply an ascal nurse tissue. The type of perithecium illustrated by *Sphaerostilbe aurantiicola* is not unique among the Hypocreales. My own unpublished observations indicate that the perithecium of *Creonectria purpurea* (L.) Seaver has a similar structure. In addition, Vincens' figure of an

early stage of perithecial development in *Nectria Ribis* (27, fig. 40) shows a striking resemblance to my figure 36. of *Sphaerostilbe aurantiicola*. Here also may be seen the palisade of vertical hyphae growing downward from the ostiolar region of the wall to fill the perithecial cavity. Vincens states that later true paraphyses originate in the base of the perithecium, but his fig. 41 of a perithecium in which asci are developing shows the perithecium still filled with vertical hyphae attached to the apical part of the wall. He records a similar condition of *Hypocrea gelatinosa* (27).

Crozier Formation. Accounts of the origin of the ascus are at variance. Vincens (27) stated that no croziers were observed in *Hypomyces aurantiius* or in *Nectria Ribis*. In *Claviceps microcephala* and *Epichloe typhina* (27) he described the asci as originating from direct outgrowths of binucleate cells, but Dangeard (6) found that in the latter species asci are formed from croziers. Jenkins (14) reported that the asci of *Cordyceps agariciformia* may be formed either from croziers or directly. Croziers have been described in *Peckiella lateritia* (Moreau 20), *Thyronectria denigrata* (Lieneman 16), *Hypomyces Thiryanus* (Maire 17), *Cordyceps militaris* (Varitchak 25, 26), *Claviceps purpurea* (Killian 15), and *Epichloe Bambusae* (Gaümann 12). Formation of asci from croziers was observed in *Sphaerostilbe aurantiicola* if the hymenium was teased apart although it was impossible to demonstrate them satisfactorily in sectioned material. This indicates that it might be possible to demonstrate croziers in other species in which they have not been observed if proper methods were employed. It is probable that formation of asci from croziers is characteristic of the order.

Cytology of the Ascus. In the few species of Hypocreales upon which studies of the cytology of the ascus have been made there is the usual fusion of two nuclei in the young ascus to form a single fusion nucleus which enlarges and undergoes three successive divisions. There is no evidence of nuclear fusions other than those which occur in the young ascus at any stage in the life history of any species studied. Consequently, there is probably only a single meiosis prior to spore formation in the ascus. The division figures are small, and it is difficult to distinguish chromosomes with certainty. Chromosome counts have, however, been made previously for three species. According to Maire (17) the chromosome number of *Hypomyces Thiryanus* is four. The counts of Jenkins (14) upon *Cordyceps agriciformia* and of Varitchak (26) upon *Cordyceps militaris* agree with my own upon *Sphaerostilbe aurantiicola*. In these three species the chromosome number appears to to be two. In *Sphaerostilbe aurantiicola* as in *Cordyceps agariciformia* (Jenkins 14) there is no evidence that astral rays function in spore delimitation. Cleavage furrows resulting from vacuolization cut out the ascospores. The ascospores of *Hypomyces Thiryanus* (Maire 17) and of *Cordyceps*

militaris (Varitchak 26), however, have been reported to be delimited by astral rays. Observation of such structures may be conditioned by the technical methods employed.

DISCUSSION

From a consideration of the preceding review of perithecial development in the Hypocreales it seems that at least the following five types of ascocarp may be recognized in this order:

1. Asci formed in perithecia consisting of a perithecial wall perforated by a periphysate ostiole and lined in the basal region with a hymenium of paraphyses and asci. *Nectria galligena, Hypomyces aurantiius, Thyronectria denigrata.*

2. Perithecial wall and ostiole present, paraphyses lacking, perithecial cavity filled with a palisade of simple hyphae growing downward from the apical region of the perithecial wall and forming a nurse tissue for the asci which grow up among them. *Sphaerostilbe aurantiicola, Nectria Ribis* (?), *Hypocrea gelatinosa* (?), *Creonectria purpurea.*

3. Perithecial wall and ostiole present, paraphyses lacking, asci formed within a pseudoparenchymatous tissue which fills the young perithecium and disintegrates as the developing asci push up into it. *Nectria Ipomoeae.*

4. Perithecial wall present but often poorly developed, ostiole present, paraphyses lacking, asci filling the perithecial cavity as it develops. *Cordyceps militaris, Cordyceps agariciformia, Claviceps purpurea, Claviceps microcephala, Epichloe Bambusae.*

5. Asci formed in locules within a stroma, arising in groups within the stroma and by their growth creating the locules, perithecial wall, ostiole, and paraphyses lacking. *Epichloe typhina.*

Miller (19) has given the following definition of a perithecium: "True perithecia with walls that arise from the basal cells of the archicarp, the upper wall cells proliferating upward to form a definite ostiole, asci forming a wall layer, interspersed with true periphyses in the ostiolar canal." In another paper (18) he stated, "When there is a true wall there is no pseudoparenchyma in the centrum, there are true paraphyses and periphyses, concave hymenial layer, and the ostiolum is schizogenous in type." While this definition is satisfactory for the majority of perithecia, there are many variations in perithecial structure which it does not recognize. It is evident that the type of centrum described by Miller is not characteristic of all perithecia. Upon the basis of structure of the centrum, perithecia of species in the Hypocreales may be separated into four groups illustrated by the above mentioned types 1, 2, 3, and 4.

The only character common to all perithecia is the perithecial wall penetrated by a schizogenously-formed, periphysate ostiole. In some species the wall may be derived entirely from the stalk cells of the archicarp; in others

it is certainly derived, at least in part, from adjacent vegetative hyphae. In either case formation of an archicarp is generally the stimulus for the initiation of the perithecial wall. Cayley's (4) observations upon *Nectria galligena* suggest, however, the possibility that in some species perithecial wall may be initiated prior to the formation of archicarps. The perithecial walls of some species are not well developed. In *Epichloe typhina*, the species upon which the above type 5 is based, they are lacking entirely. Yet in characteristics other than the presence of a perithecial wall (nature of the stroma, development of asci, and type of ascospores) it is clearly related to the Claviceptaceae. In the Claviceptaceae, and possibly in other groups, there has apparently been a reduction in the perithecial wall resulting in the production of stromatic ascocarps.

SUMMARY

Sphaerostilbe aurantiicola (B. & Br.) Petch is a Hypocreaceous fungus which occurs throughout the world as a parasite upon various species of scale insects. It is of economic importance in the control of the San Jose scale in Florida. The present observations upon its morphology are based upon material from the obscure scale [*Chrysomphalus obscurus* (Comst.)] of water oak (*Quercus nigra* L.) in Georgia.

The fungus completely destroys the body of the infected scale and forms a plectenchymatous stroma between the shield of the scale and the bark of its host. It does not penetrate the bark.

Pulvinate or stilboid outgrowths of the stroma from the margin or through the surface of the scale produce clusters of conidiophores which abstrict fusiform conidia from their tips.

Perithecia are initiated by coiled ascogonia composed of enlarged, deeply staining, multinucleate cells which are formed within the stromatic stalk below the conidial head or in the margin of the stroma. Branches of the surrounding vegetative hyphae invest the ascogonium to form the perithecial wall. From the ascogonial cells arise ascogenous hyphae which later produce asci by means of croziers. The ascogonia disintegrate. No paraphyses are formed. Instead, the perithecial cavity is filled by a palisade of vertical hyphae that grow downward from the apical part of the wall of the perithecium and form a nurse tissue for the asci. A periphysate, schizogenously formed ostiole develops at the apex of the perithecium. At maturity the perithecia are clustered upon the surface of the stroma in which their basal portions are embedded. Although this type of perithecial development has not previously been described, it evidently occurs in other species of Hypocreales.

Sphaerostilbe aurantiicola has been obtained in culture from both conidia and ascorpores. The character of the mycelium and the formation of

conidia in culture are dependent upon exposure to light. Light has no effect upon rate of mycelial growth in culture.

From a review of the literature on perithecial development in the Hypocreales and a comparison of other species with *Sphaerostilbe aurantiicola* it appears that five different types of ascocarpic structure may be recognized in this order.

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 71, NO. 6, PP. 620–623 NOVEMBER, 1944

THE CYTOLOGICAL EFFECTS OF BENZENE VAPOR[1]

C. A. BERGER, E. R. WITKUS AND B. J. SULLIVAN

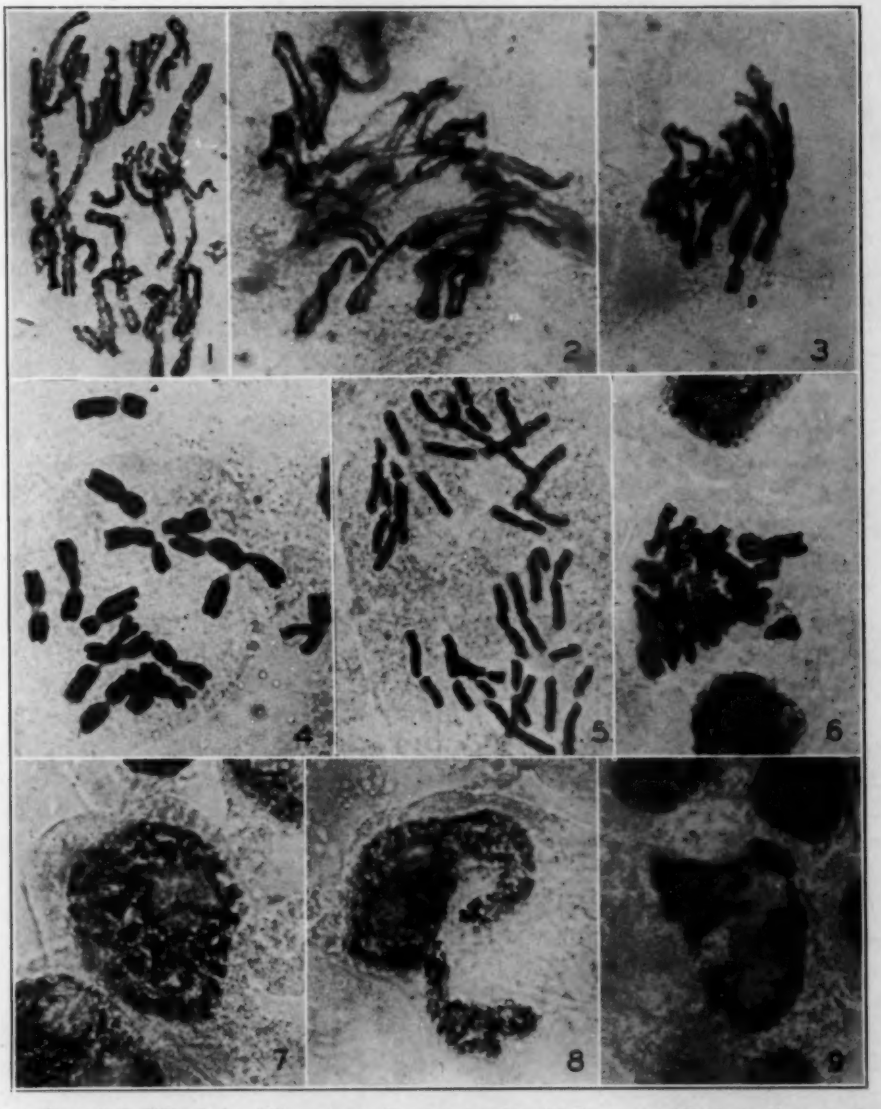
During the past year the cytological effects of several alkaloids, growth-promoting substances, and other chemical agents have been studied in this laboratory. Several of these substances contained in their respective molecules one, two, or three benzene rings and it occurred to one of us[2] that the effect of benzene itself should be investigated.

The common onion, *Allium cepa,* with the diploid chromosome number of sixteen, was used. Bulbs with young actively growing roots were placed on small beakers nearly filled with benzene. After an immersion of one hour aceto-orcein smear preparations of the root tips revealed cytological effects strikingly similar to those of colchicine, acenaphthene, and other polyploidy-inducing agents. Spindle formation was inhibited, diplo-chromosomes were formed, and tetraploid cells resulted. Liquid benzene was a powerful agent and roots treated by immersion for periods longer than one hour did not recover. It was noted, however, that young roots, too short to come into contact with the liquid benzene but growing in an atmosphere saturated with benzene vapor, developed the same type of cytological effects. Accordingly a new series of experiments was made in which roots were subjected to benzene vapor for periods of from one to six hours. It was found that the roots dried after three hours exposure to benzene vapor but this difficulty was overcome by placing the benzene vessel and the bulb in a larger closed jar containing some water. Three hours treatment with benzene vapor was found to give the best results; marked effects were obtained and the roots recovered and underwent further mitoses.

OBSERVATIONS

The most noteworthy effect of benzene treatment is a precocious separation of chromatids and a clear demonstration of half-chromatids. This effect was more evident after treatment by immersion in liquid benzene than after subjection to benzene vapor. Many cytologists believe that somatic metaphase chromosomes are quadripartite, consisting of two chromatids and four half-chromatids (see review paper of Nebel 1939), but visible evidence of this condition is difficult to obtain. In this material, after one hour of treatment with liquid benzene and no recovery period, the presence of half-chromatids is unmistakable. At late prophase, prometaphase, and early metaphase (figs. 1, 2, 3) chromatids are widely separated on both sides of the

[1] Aided by a grant from the Penrose Fund of the American Philosophical Society.
[2] Dr. E. R. Witkus.



FIGS. 1–9. Mitosis in *Allium cepa* after treatment with benzene. All photomicrographs have a magnification of ×1000 except figure 2 which is ×1200. FIG. 1. Late prophase. FIG. 2. Prometaphase. FIG. 3. Metaphase. FIG. 4. Late metaphase, diplo-chromosomes. FIG. 5. 4n chromosomes after delayed division of SA-regions. FIG. 6. Early reversion stage. FIGS. 7, 8, 9. Reversion stages.

undivided SA-region (spindle attachment region) and are relationally coiled. In favorable preparations each chromatid is clearly seen to consist of two threads (figs. 1, 2, 3). Sister half-chromatids appear to be in paranemic relationship but the smallness of the structures does not permit absolute certainty on this point.

Other effects of benzene and benzene vapor are as follows. As with colchicine, acenaphthene, and other chemical agents the division of the SA-region is delayed by one hour of immersion in liquid benzene or from one to three hours of vapor treatment, and the metaphase chromosomes continue to contract, forming typical diplo-chromosomes (fig. 4). This supercontraction may continue, resulting in very short, thick diplo-chromosomes with widely divergent arms as reported for colchicine-treated material (Levan 1938; Berger & Witkus 1943 and others). The SA-region eventually divides and the tetraploid number of chromosomes are scattered throughout the cell (fig. 5). The achromatic spindle is either prevented from forming or destroyed and there is no anaphase movement of the chromosomes, no daughter telophase nuclei, and no cell plate formation. The chromosomes, either scattered or loosely clumped, begin the reversion process which will result in a tetraploid resting nucleus. The chromosomes begin to despiralize and to assume the structural details of anaphase and telophase chromosomes (figs. 6, 7). Tetraploid telophase nuclei are frequently irregular in shape (figs. 8, 9). The above-mentioned effects are all found in material fixed immediately after treatment and allowed no period of recovery.

Cells that were not in mitosis during treatment do not become polyploid and begin to divide as soon as the roots are placed in water. Many diploid mitoses are found in the first hour of recovery. Cells that were in division during treatment and had become tetraploid do not undergo mitosis during the first three days of recovery but after that period tetraploid mitosis is found. Thus while the root as a whole recovers quickly, the cells which became tetraploid during the treatment require several days to adjust themselves to the newly acquired tetraploid nuclear condition before they are again ready for mitotic division.

SUMMARY

1. Benzene and benzene vapor produce cytological effects similar to those produced by colchicine.

2. Spindle formation is inhibited and division of the SA-region is delayed. Diplo-chromosomes are formed and tetraploid cells result.

3. In root tip divisions in *Allium*, chromatids are widely separated and half-chromatids become clearly visible at prometaphase.

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MORPHOLOGY OF THE RICE SPIKELET

VIRGINIA MICHAUD[1]

Some greenhouse plants of *Oryza sativa* have recently produced anomalous structures which may prove helpful in clarifying the morphology of the rice spikelet. The culture, which originated from the caryopses of plants collected by Charles DeVol in China in 1940, has reseeded from time to time and maintained itself for three years.

The single flower of a normal rice spikelet (fig. 1) is enclosed in two indurated bracts; one of these is in the position of a lemma and has the characteristics of a lemma, but the other, which is in the position of a palea, is unlike a palea in that it is single-keeled. Below these are two very small bracts which remain attached at the base of the lemma when the mature fruit disarticulates. Beneath the articulation is a structure which forms a sort of cup around the base of the spikelet.

The rice spikelet has long been a subject of special interest to grass morphologists. The most commonly accepted interpretation regards the two small bracts just above the articulation as glumes, the lower of the two bracts surrounding the flower as the lemma, and the upper as the palea. In most taxonomic works no particular significance is attached to the structure below the articulation. Among the interpretations differing from this there are two which are important.

Mrs. Arber (1934, p. 184) regards the cup below the articulation as the equivalent of a pair of extremely reduced glumes, the next two bracts as sterile lemmas, and the last two as a lemma and a palea. Eichler's diagram (1875, p. 125) of the rice spikelet indicates six bracts, four of which are called glumes. Schuster (1910) interprets this to mean that there are two bracts (stunted glumes) below the structures ordinarily regarded as glumes, these presumably represented by the cup below the articulation.

The second interpretation involves the identity of the upper two bracts. In a hypothesis recently and independently put forth by two workers, N. F. Peterson (1935), of the Univ. of Nebraska, and L. R. Parodi (1939), of Argentina, it is proposed that the spikelet is not one-flowered but represents the union of two florets in which the paleas of both and the pistil of one have disappeared. The two bracts enclosing the flower are then considered as the two fertile lemmas. Parodi (1941) found support for his idea in abnormal spikelets in which he observed two pistils and two linear, binerved paleas

[1] The writer wishes to express her appreciation to Dr. Paul Weatherwax for his helpful suggestions in the preparation of the manuscript.

within the covering of the two rigid bracts. In his description there is no reference to structures below the lower lemma. A similar spikelet is pictured in cross section by Schuster (1910, fig. 14), but he does not explain the figure.

The four abnormal spikelets which I have found give evidence in support of Mrs. Arber's interpretation and raise a question concerning the explanation given by Peterson and by Parodi. All of the spikelets had either more than one flower or more than two indurated bracts. The lower floret of one spikelet contained a flower with a pistil, two lodicules and two stamens. The pistil had four styles. Both the lemma and the palea were indurate and carinate. One stamen was in the normal dorsal position, and the other was in the median position directly opposite. The upper floret was normal. An empty bract was present below the lower lemma.

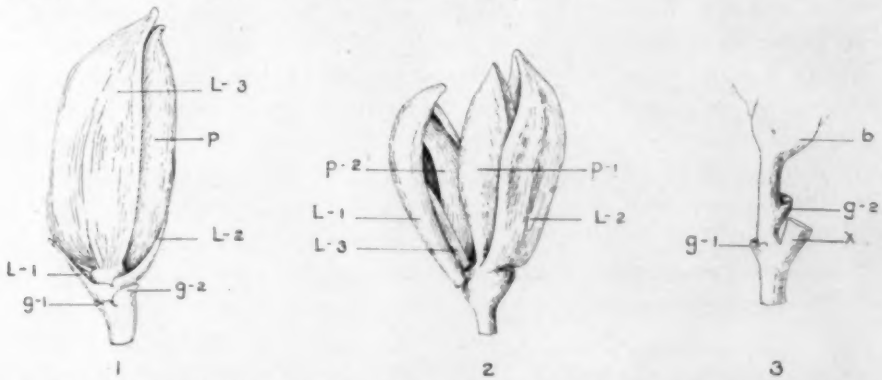

FIG. 1. Normal spikelet of rice. FIG. 2. Portion of abnormal spikelet showing three well-developed lemmas and two paleas. FIG. 3. Portion of abnormal spikelet below lemmas. b, base of first lemma; L–1, L–2, L–3, first, second and third lemmas respectively; g–1, g–2, first and second glumes; x, portion of rachis.

A second spikelet had three lemmas (fig. 2). The lowermost was empty, the second was fertile and normal, and the third subtended an abortive flower consisting of a one-styled ovary and a palea. As in the first spikelet, the paleas were similar to the lemmas in texture and form, although the abortive palea was smaller and its margins were inrolled. The other two spikelets showed the second bract or "glume" in different degrees of similarity to a normal lemma, but in both cases only one other bract was present below. In all the spikelets the cup below the position of normal articulation was divided into two or, as in one case, three separate scales, and there was no distinct articulation (fig. 3).

The presence of a lemma-like structure in the position of one of the "glumes" in three of the abnormal spikelets, and the presence of three such structures and no "glumes" in one spikelet, presents a fair indication that the bracts which in the taxonomic literature have been called glumes are in

reality reduced sterile lemmas. The scales, which I have assumed to represent the cup, could then be considered as extremely reduced glumes. Such an interpretation of the rice spikelet brings the Oryzeae very close to the Phalarideae as suggested by Mrs. Arber (1934, p. 184). What the extra small scale in one spikelet represents is not clear. It may be another reduced lemma.

If we assume that the anomalies which have been described represent a true picture of the homologies of the bracts in the rice spikelet, a question occurs in reference to the interpretation proposed by Peterson and by Parodi. In two spikelets more than one lemma was observed to have in its axil a bract similar to it in shape and texture. That is, the extra florets were constructed like the single floret in a normal spikelet. Are these also to be considered the result of fusion of two flowers? If this is true, then it will be necessary to reconsider the spikelet in terms of that hypothesis. If each lemma on a given axis has another in its axil it is a strong indication that a branching system is involved. To regard the rice spikelet as an extremely reduced branching system of which the lemmas represent entire spikelets would indeed set the genus *Oryza* off as a group in which the spikelet differs in origin from that of other grasses, and would lend support to Parodi's suggestion that the Oryzeae constitute a separate subfamily (Parodi 1939).

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FURTHER POLLEN STUDIES OF PEAT BOGS ON THE PACIFIC COAST OF OREGON AND WASHINGTON[1]

HENRY P. HANSEN

INTRODUCTION

The moist climate of the Pacific Coast of Oregon and Washington and the progression of a post-Pleistocene marine cycle of a submergent shoreline has resulted in the formation of many freshwater ponds and subsequent hydrarch succession forming peat deposits. Many stages of hydrarch succession are to be found, from those in recently formed sand-dune lakes, supporting early submerged seres, to mature bogs covered with forests. This area lies beyond the limits of Pleistocene glaciation, but this geologic event has apparently been indirectly responsible for conditions favoring organic sedimentation during postglacial times. The nourishment of the continental ice sheet caused a lowering of sea level, which permitted down-cutting of streams emptying into the ocean. During deglaciation raising of sea level drowned the valley mouths of streams for many miles inland (Fenneman 1931). The marine cycle of submergence since then has resulted in the formation of several kinds of lakes, apparently with some chronological consistency. This is shown by the depth of the peat deposits, particularly on the margin of the larger lakes, formed in the blocked tributaries of the major streams. Ponding effected by movement of shore sand has taken place at later dates, and in fact is occurring continually along the coast, in the sand-dune zone. This includes embayment of small streams by spits and bars, blocking of small streams flowing parallel with the shore, and the formation of depressions by migrating sand dunes and possibly in some cases by deflation. Lakes formed in the tributaries of the larger streams at some distance from the ocean support the deepest peat deposits, and thus hold the probability of antedating those formed in the sand-dune zone. It is difficult to assign an age to these dune bogs, and an estimation must be based upon the depth of the peat and the average rate of deposition as determined by the average depth of the several profiles studied. Shifting of sand not only forms new depressions for potential hydrarch succession, but also buries bogs in varying stages of development. This is well shown by a stratum of fossil peat enclosed in terrace sands of a sea cliff near Newport, Oregon (Hansen & Allison 1942). The peat layer

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is overlain with 40 feet of sand which may be of either subaqueous or eolian origin. A record of forest succession from pioneer forests of lodgepole pine to climax forests of spruce and hemlock is revealed by pollen analysis of the sediments. Thus it can be seen that the chronology of coastal peat bogs is indefinite, with many different ages represented and considerable overlapping of their periods of recorded time.

LOCATION AND CHARACTERISTICS OF THE BOGS

This study is concerned with a series of six peat profiles extending from Hauser, Oregon, north to Hoquiam, Washington, a distance of about 265 miles. In order, beginning at the south, the peat profiles are located near the following towns: Hauser, Newport, and Gearhart in Oregon; Ilwaco, Grayland, and Hoquiam in Washington. Those located near Hauser, Newport, Ilwaco, and Grayland have been formed in shallow sand dune lakes within a mile or two of the ocean. The bog at Gearhart has developed in a small stream valley, somewhat inland from the sand-dune zone, and is the deepest of the profiles. That near Hoquiam lies near sea level on the north side of Grays Harbor, just west of the mouth of the Humptulips River. It apparently owes its origin to a eustatic rise in sea level, causing drowning of stream mouths. Several feet of mud underlying the organic sediments suggest tideflat conditions for some time before freshwater hydrarch plant succession began. The existence of estuarine conditions in this area further suggests this possibility. The bogs vary in depth, the deepest being 7 m. at Gearhart; those at Hauser and Newport, 1.0 m.; near Ilwaco, 2.8 m.; at Grayland, 2.1 m.; and that near Hoquiam, 4.4 m. The bog at Gearhart is underlain with silt and clay, and all the others except at Hoquiam are underlain directly with sand. In sand-dune bogs, the organic sediments are sharply defined stratigraphically from the underlying sand, with no gradation into silt, clay, and limnic peat, such as usually occurs in inland bogs, both in the glaciated and unglaciated regions. This is due to the presence of only sand adjacent to the ponds, which prevents the income of fine silts and clays before organic sedimentation gets under way.

All the bogs are of the *Sphagnum* type. Portions of some of them have been drained and scalped for cranberry culture, which is an important industry along the coast of Oregon and Washington. The following species of plants are common to all the bogs; Labrador tea (*Ledum columbianum*), bog laurel (*Kalmia polifolia*), cranberry (*Vaccinium oxycoccus*), salal (*Gaultheria shallon*), sweet gale (*Myrica gale*), hardhack (*Spiraea douglasii*), skunk cabbage (*Lysichitum americanum*), cascara (*Rhamnus purshiana*), red alder (*Alnus rubra*), deer fern (*Struthiopteris spicant*), and yellow pond-lily (*Nymphozanthus polysepalus*). All bogs are in the climax stage and are being invaded by forest tree species. Generally, lodgepole pine

(*Pinus contorta*) is the pioneer and most abundant arboreal invader of the coast bogs, but occasionally Sitka spruce (*Picea sitchesis*) may be the initial invader. Other species that early encroach upon the climax bog are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and occasionally Douglas fir (*Pseudotsuga taxifolia*). Along the southern half of the Oregon coast, Port Orford cedar (*Chamaecyparis lawsoniana*) is found with lodgepole pine. The determining factor in the order of arboreal bog invasion seems to be the availability and proximity of the several species. Lodgepole pine is usually the most abundant species in the sand-dune zone, and is usually preponderant as a seed disperser onto the bog surface. Observations show that either Sitka spruce or western hemlock may be the first invader if their propagules are available. On the Newport bog, hemlock is abundant on the eastern part, but not on the western edge. This is evidently due to the presence of hemlock forests adjacent to the eastern margin of the bog, while the forests to the west are composed of lodgepole pine and spruce. The prevailing westerly winds are a further factor favoring lodgepole invasion, as the forests located windward to the site of the bogs are usually composed of a preponderance of this species. The abundance of lodgepole pine on climax bogs is reflected in the pollen proportions of the upper horizons of peat, and tends to distort the recorded composition of the adjacent forests.

FORESTS OF ADJACENT AREAS

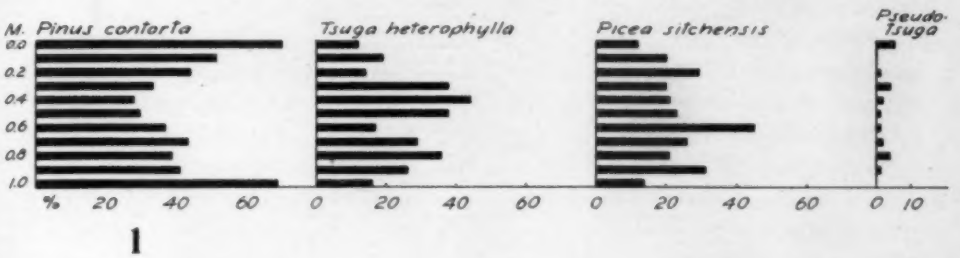
All six bogs lie within the Humid Transition life area (Bailey 1936). A narrow zone, several miles in width from the ocean to the Coast Range along the coast of Oregon and Washington, is spoken of as the fog belt because of the heavy precipitation. The mean annual rainfall at stations nearest the site of the sediments of this study is as follows: Newport, 67 inches; Astoria, 76 inches; and Aberdeen, Wash., 81 inches. Although the coastal strip is a part of the area designated as the hemlock-cedar climax of the Coast Forest (Weaver and Clements 1938), cedar is of minor importance in the forest complex. The principal dominants of the fog belt forests are lodgepole pine, Sitka spruce, and western hemlock. As the first is not a climax species, the coastal strip forests may be classified as the spruce-hemlock climax. Lodgepole pine is usually the first arboreal invader of sand dunes after they have been somewhat stabilized by lesser vegetation. Thickets of lodgepole near the ocean shore are low and rounded owing to sand-shear caused by the abrasive action of landward-borne sand. Individuals are much misshapen, and often resemble the Krummholz form of trees at timberline. Occasionally a specimen of spruce is found in the thickets of lodgepole, but hemlock has not been observed under these conditions. Farther inland, lodgepole assumes a tall, straight form and dense thickets serve as a windbreak for other species. Leeward to the pine zone, and mixed with it to some extent, are spruce and

hemlock. These species become progressively more abundant farther inland, lodgepole gradually thinning out because of its intolerance for shade. Still farther away from the ocean, Douglas fir enters the forest complex, while spruce becomes less abundant, gradually giving way to hemlock and Douglas fir. Hemlock in turn surrenders its predominance to Douglas fir in the Coast Range to the east. When the forests on the sand dunes are burned, lodgepole pine may regain its preponderance; or farther from the ocean Douglas fir often makes its appearance and become locally predominant until replaced by spruce and hemlock. Other forest tree species apparently within range of pollen dispersal to the site of the sediments are western white pine (*Pinus monticola*), lowland white fir (*Abies grandis*), noble fir (*A. nobilis*), and silver fir (*A. amabilis*). The most important broadleaf species are red alder, bigleaf maple (*Acer macrophyllum*), and black cottonwood (*Populus trichocarpa*).

FOREST SUCCESSION

Although the general forest physiognomy of the coastal strip in which the peat profiles are situated is more or less homogeneous, the recorded forest succession for the period represented varies somewhat in the several areas. This may be due to the different ages of the bogs, the varying forest composition and stages of succession during initial sedimentation, the different trends of forest succession because of differences in topography, varying degrees and periods of sand movement, and the position of the bog in relation to sand dunes, the ocean, prevailing winds, and the adjacent forests. Perhaps the most important factor that influences forest succession and tends to interrupt the normal succession along the Oregon and Washington coast is sand-dune movement. Periodic shifting of dunes may bury forests in various stages of succession, from the pioneer forests of lodgepole pine to more mature forests of spruce and hemlock. The first are more prone to be destroyed because of their proximity to the ocean and their establishment on less stabilized soil than the climax forest. The destruction of the lodgepole forests is perhaps more readily reflected in the pollen profiles than the climax forests, because the bogs usually lie leeward to the pine zone. Thus, fluctuations in the pollen profiles of the several species, when contrary with one another, or one group with another, may denote relative rather than actual changes of the recorded species. One can assume that fluctuations in pollen profiles of coast bogs are probably more often a result of changes in the actual abundance of lodgepole pine, rather than in spruce or hemlock. The location of pine forests, largely windward to the bogs, and the greater amount of pollen produced by this species undoubtedly cause over-representation by its pollen. The maturation of lodgepole pine at a much earlier age than the other species gives it more maneuverability in an unstabilized dune

area. Not only is it better adapted to invade newly formed dunes, but it is also better able as a forest to recover after, or even during, its destruction by burying or fire than spruce or hemlock, which require many years before attaining seed-bearing age. Spruce and hemlock forests producing relatively



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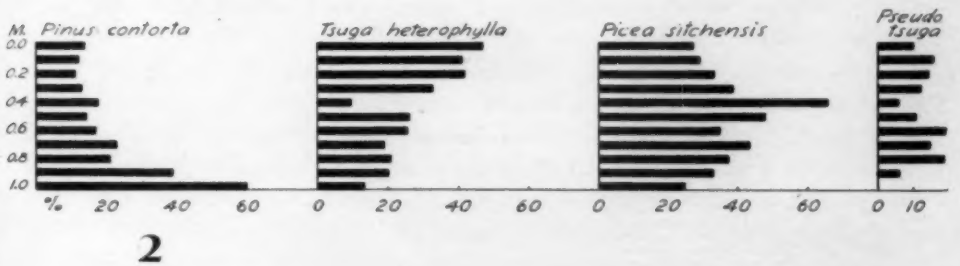

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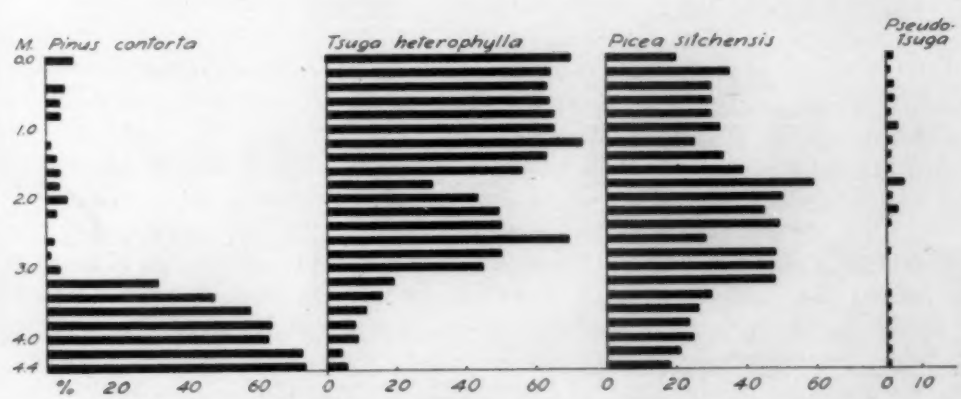

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FIG. 1. Pollen profiles, Newport, Oregon. FIG. 2. Pollen profiles, Hauser, Oregon. FIG. 3. Pollen profiles, Hoquiam, Washington.

less pollen and lying largely leeward to the bogs are probably generally under-represented in the pollen profiles.

The similarity in the composition of the peat of the six profiles suggests about the same rate of deposition. The profile near Gearhart, being the deep-

est, would also represent the greatest period of time for its deposition. Its location and method of formation also indicate a greater possible age, and it is the only profile that seems to hold the potentiality of representing most or all of postglacial time. The trends of adjacent forest succession as recorded in the profile seem to substantiate this theory.

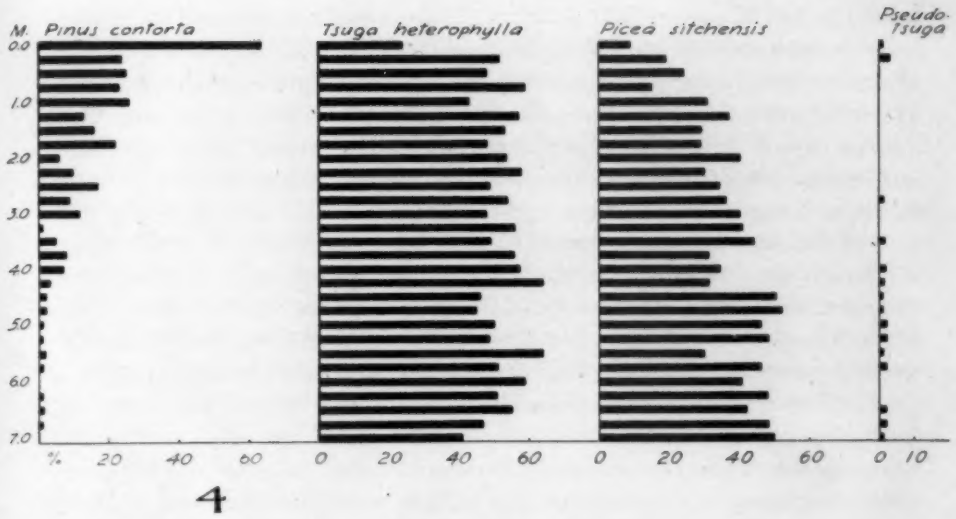
Three of the profiles, those at Newport, Hauser, and Hoquiam reveal a preponderance of lodgepole pine in the lower levels (figs. 1, 2, 3). This is also shown in two sand-dune bogs farther south on the Oregon coast, near Bandon and Marshfield (Hansen 1943). Lodgepole pine has generally been the pioneer postglacial invader in the Pacific Northwest, especially in the glaciated region. In these areas, however, forest succession started anew as the ice retreated, whereas the coastal strip of Oregon and Washington was probably forested during the glacial period with the present day species. In the Hauser profile lodgepole pine is recorded as having gradually declined from 60 per cent at the bottom to 14 per cent at the top. At Newport, lodgepole declines from its maximum of 69 per cent at the bottom to its minimum of 28 per cent at 0.4 m., and then increases to 66 per cent at the surface. The resurgence of lodgepole at the surface reflects its invasion of the bog and its abundance in sandy areas west of the bog. Lodgepole is not so abundant adjacent to the Hauser bog, and the surface has been scalped for cranberry culture, with the elimination of much of the source for its pollen.

In the Hoquiam profile, lodgepole is recorded to its maximum of 74 per cent at the lowest horizon, from which level it abruptly declines to only 4 per cent at 3 m., and then fluctuates between nothing and 8 per cent to the top. There is less dune area in this vicinity, much of the adjacent region consisting of low swampy ground forested with hardwood species, and gravelly knolls covered with climax forest.

In the other three profiles, lodgepole is recorded to less than 15 per cent at the lowest horizons, but shows slightly different trends upward in the profiles. At Gearhart it shows a general increase upward, to reach its maximum of 63 per cent at the surface (fig. 4). The accelerated increase in more recent time marks its invasion of the bog. Apparently the Gearhart bog had its inception when the adjacent forests existed in the climax stage. Since that time, the major trend of pine has been its more recent encroachment upon the bog. A similar situation apparently was present in the vicinity of a 12 m. profile farther south, near Florence, Oregon (Hansen 1941). Here, in an area inland from the sand-dune zone, climax forests of spruce and hemlock also existed when sedimentation was begun. In the Ilwaco profile, pine is revealed as having fluctuated considerably during the period represented (fig. 5). It

Explanation of figures 4–6

FIG. 4. Pollen profiles, Gearhart, Oregon. FIG. 5. Pollen profiles, Ilwaco, Washington. FIG. 6. Pollen profiles, Grayland, Washington.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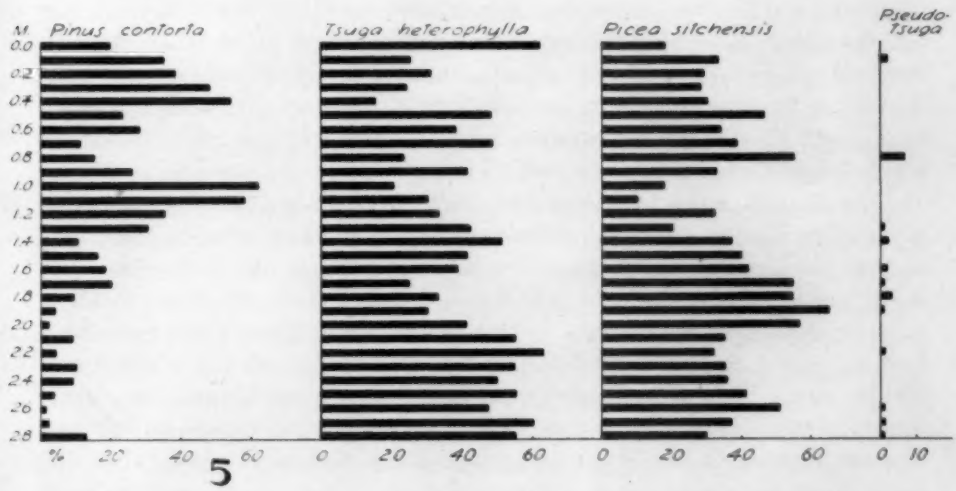
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Tsuga heterophylla
Picea sitchensis
Pseudo-Tsuga
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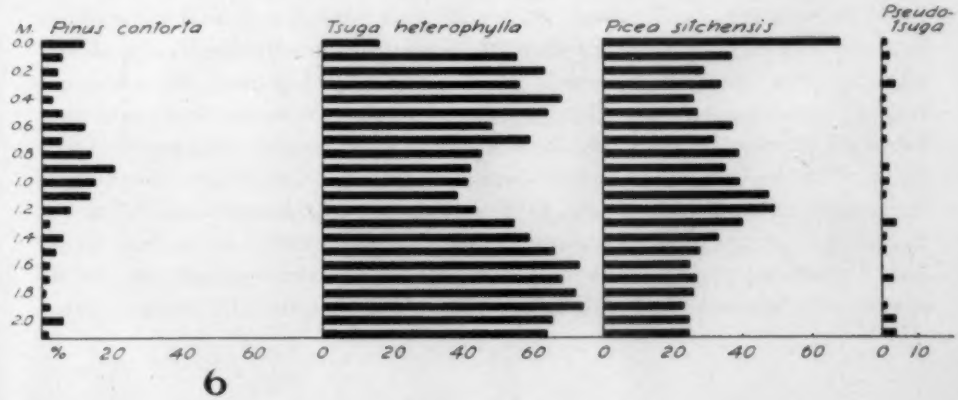
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6

is recorded as 13 per cent at the bottom, fluctuates between 1 and 20 per cent to 1.4 m., and sharply increases to its maximum of 62 per cent at 1 m. It then abruptly declines to 11 per cent at 0.7 m., followed by a marked increase to 54 per cent at 0.4 m., and then a final decline to 20 per cent at the top. These marked trends evidently record extensive and periodic dune movement, burying forests of lodgepole on one hand, and providing new areas for its invasion on the other. The Ilwaco profile is located in the most extensive dune area of the six bogs, at the mouth of the Columbia River. Here the strong winds follow up the Columbia, causing movement of sand from both the west and the south. The vast Long Beach spit extends for 15 miles to the north. The presence of large bog areas in this region has probably been responsible also for lodgepole pine fluctuation. Invasion of bogs occurred at various times, as they reached the climax stage, and such invasions are undoubtedly represented in the pollen profiles by an increase in pine pollen. The presence of charred peat at 1.0 m. suggests that fire may also have been a factor in the abrupt increase of pine to its maximum at this horizon. In the Grayland bog pine is recorded as only 2 per cent at the lowest level, from which point it increases to its maximum of 21 per cent at 0.9 m. (fig. 6). It declines to 6 per cent at 0.1 m. and then increases to 12 per cent at the top. The latter increase reflects its limited encroachment upon the bog in recent time. Both the Ilwaco and Grayland bogs apparently had their initiation when climax forests existed in their vicinity.

The climax species, spruce and hemlock, show considerable fluctuation in all profiles. Most of these fluctuations are opposed to each other, rather than to that of pine, because the latter reveals many trends that are neither opposite nor similar to those of hemlock and spruce, either collectively or as to individual species. An increase in spruce and hemlock from the bottom to half-way up in the profile is contrary to pine decrease. A continued sharp rise in spruce to 66 per cent at 0.4 m., however, is contemporaneous with a decline of hemlock, and pine shows a slight increase to this same level (fig. 2). A sharp reversal of trends for spruce and hemlock from this horizon to the surface denotes continued competition between these species, as lodgepole remains constant. In the Newport profile, spruce and hemlock trends are opposed at every level except from the bottom to that immediately above (fig. 1). The trend of lodgepole pine apparently has been independent throughout the entire period represented. In the Gearhart bog, again the recorded trends of spruce and hemlock have been largely contrary to each other, with the latter predominant throughout, while lodgepole reflects only its invasion of the bog itself (fig. 4). The Ilwaco profile discloses several short period fluctuations of all three species (fig. 5). Some involve spruce and hemlock fluctuating oppositely to lodgepole, others concern contrary trends of spruce and hemlock, and still others denote fluctuations of lodgepole con-

trary to either spruce or hemlock. The major fluctuations of pine suggest accelerated dune movement, first burying pine forests, then supporting pine invasion, and finally replacement of pine with spruce and hemlock as stabilization of edaphic conditions progressed. The occurrence of charred peat at 1 m., the level of pine maximum, suggests the possibility of fire as having been instrumental in the development of this trend. The pollen-bearing sediments at Grayland also were apparently inaugurated when the adjacent forests existed in the climax stage (fig. 6). The trends of spruce are largely the converse of hemlock, whereas those of lodgepole seem to be independent. From its initial predominance, hemlock declines whereas spruce increases to 1.1 m., then their trends are reversed to the horizon immediately below the surface, where hemlock again decreases and spruce increases to the top, the latter being preponderant. There are several possible events suggested by these trends. Fire may have destroyed the hemlock forests, increasing the relative abundance of spruce and pine. Sand dune movement may have permitted an increase in spruce and pine. A third possibility for spruce expansion is its invasion of other climax bog areas in the vicinity. The resurgence of hemlock from 1.1 m. to immediately below the surface suggests normal forest succession. The final increase of spruce at the expense of hemlock may mark the invasion of spruce on the bog. In the Hoquiam sediments, the trends of spruce and hemlock are opposed throughout the profile. Hemlock reveals an increase from 6 per cent at the bottom to 71 per cent at 2.6 m., with spruce remaining constant. Then with several minor fluctuations, hemlock attains its maximum of 73 per cent at 1.2 m. and spruce declines to 25 per cent at the same level, and then both species remain generally constant to the top (fig. 3). Dune movement has apparently played a minor role in forest succession in this region, the expansion of lodgepole pine to 21 per cent at 0.9 m. after its initial decline being the only period indicating unstabilized edaphic conditions.

Other forest tree species are only sparsely and sporadically represented. In the Hauser profile, Douglas fir is recorded as high as 20 per cent, and closely follows the trends of hemlock, while in the others it has a limited representation and not at every horizon. The bogs are located windward to the Douglas fir forests of the Coast Range. Other species recorded are western white pine, lowland white fir, noble fir, and silver fir. A non-indicator of adjacent forest succession consistently represented by its pollen in appreciable proportions is red alder. Species confined largely to the bogs, which provide abundant pollen at various levels, are myrtle, willow, maple, several species of Ericaceae, sedge, yellow pond-lily, and cattail. The pollen proportions of these species mark the development of hydrarch succession from submerged to climax seres.

There seems to be little evidence for climatic trends in the pollen profiles of the several species represented. There probably have been slight climatic changes during the post-Pleistocene along the coast of Oregon and Washington, because of the moderating influence of the ocean. The principal factor influencing forest succession has probably been sand movement. The inland movement of sand modifies and retards the rate of forest succession, and in some cases terminates it by burying forests. The formation of spits and bars and the building up of the beach provide primary areas for succession. Periods of extensive sand movement may reflect climatic changes farther inland, bringing about increased wind velocity for periods of time sufficient to cause considerable shifting of sand. Eustatic changes in sea level may also be reflected by increased sand movement. Emergence of land may have provided more eolian material and new areas suitable for primary forest succession. There apparently are many complex variables involved in initiating sand movement and the forest succession which it controls to a large extent. Most of these seem to be intangible as far as their application to interpretation of pollen profiles is concerned.

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 71, NO. 6, P. 637 NOVEMBER, 1944

STUDIES ON AMERICAN HEPATICAE—V. TWO NOMENCLATURAL CHANGES IN CERATOLEJEUNEA

MARGARET FULFORD

The following new species and new combination have resulted from a recent study of the genus *Ceratolejeunea:*

Ceratolejeunea grandibracteolata Fulford, sp. nov. *Ceratolejeunea subserrata* Spruce, Hep. Sprue. (not *L.* (*Cerato-Lejeunea*) *variabilis* var. *subserrata* Spruce, Trans. & Proc. Bot. Soc. [Edinburgh] **15**: 207. 1884).

Caules ad 2.5 cm. longi, 1.2 mm. lati, rufobrunnei; folia grandia, oblonga, apice lato, rotundato, integra vel leviter dentata; dente apicali lobuli brevi, curvo, obtuse acuminato; utriculis saepe praesentibus; cellulae 20–24 μ, trigoniis conspicuis, ocellis geminatis, basilaribus; amphigastria grandia, orbicularia: dioica; bracteae femineae lobus late ovatus, lobulo explanato, oblongo, margine integro; bracteolus connatus, late ovatus, bifidus ad partem tertiam longitudinis, margine integro: perianthium emergens, cornibus angustis, brevibus, divaricatis: rami masculi non visi.

Ceratolejeunea flagelliformis (Steph.) Fulford, comb. nov. *Ceratolejeunea spinosa* var. *flagelliformis* Stephani, Hedwigia **34**: 238. 1895. *Lejeunea* (*Ceratolejeunea*) *flabelliforme* Stephani. Hepat. in Duss, Muscinées Ant. Franç. 13. 1903 The characters of the perianth, which has only recently been discovered, at once set these plants apart from any of the other American species.

UNIVERSITY OF CINCINNATI
AND
THE NEW YORK BOTANICAL GARDEN

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 71, NO. 6, PP. 638–654 NOVEMBER, 1944

SPORELINGS AND VEGETATIVE REPRODUCTION IN THE GENUS CERATOLEJEUNEA*

MARGARET FULFORD

A taxonomic study of nineteen American species of the hepatic genus *Ceratolejeunea*, just completed,[1] has brought to light several stages of sporeling development in eleven of the American species and one from Java, and examples of vegetative reproduction in eight species. It is, I believe, the first time that sporelings of this genus have been identified, and also the first time that so large a number of sporelings of a genus could be compared. Although the structures of vegetative reproduction have been mentioned in the literature they were never discussed in any detail.

1. SPORELINGS

In a recent paper[2] in which several additional types of sporelings were described in the family *Lejeuneaceae*, the question whether the pattern of development was uniform for all of the species had to remain unanswered, since at that time, sporelings of only one species in any of the genera under discussion had been observed. There was also little information on the degree of variation that was to be expected in the numerous sporelings produced by one or several plants of a given species.

It is now fairly certain that the sporeling described and figured by Goebel[3] as belonging to an unknown South American genus, as well as the one described and figured by the writer,[4] as representing a further development of the type discussed by Goebel, belong to the genus *Ceratolejeunea*. These two clearly typify the basic pattern of sporeling development at its best in the genus. It may well be designated the *Ceratolejeunea* type.

The sporeling of the genus *Ceratolejeunea* (except for *C. guianensis*), is made up of a unistratose thalloid portion of two distinct stages: a filament two cells broad and four cells long which develops within the old stretched exospore; and a broader, secondary thallus four cells broad and of indefinite length. The leafy axis develops at the end of this secondary thallus.

* This work was made possible through a Marshall A. Howe Memorial Fellowship given by Mrs. Elon Huntington Hooker to the New York Botanical Garden, for the summer of 1943.

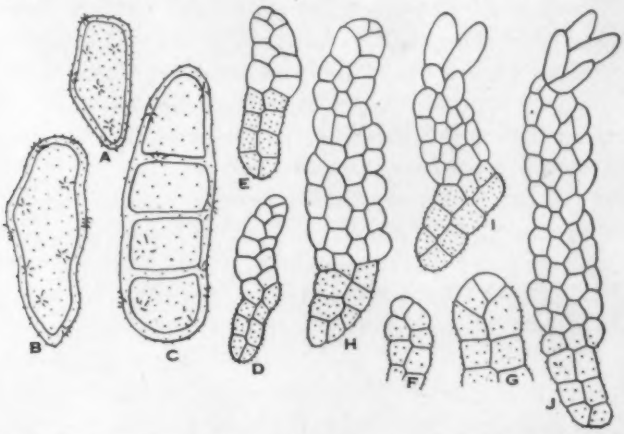
[1] **Fulford, M.** Studies on American Hepaticae—VI. Ceratolejeunea. To be published in Brittonia.

[2] ————. Development of sporelings in the Lejeuneaceae. Bull. Torrey Club **68**: 627–633. *f. 1–4.* 1942.

[3] **Goebel, K.** Organographie der Pflanzen **2**: 907. *fig. 972.* 1930.

[4] **Fulford, M.** Development of sporelings in the Lejeuneaceae. Bull. Torrey Club **68**: p. 631. fig. 3. 1942.

As in the other genera of the *Lejeuneaceae* which I have observed, the spore elongates and becomes chlorophyllose before it is shed from the capsule. Just before the capsule opens the spore is green, two or three times as long as broad, and the wall is thick and hyaline. The exospore is papillose and, in addition, has a scattered pattern of "rosettes" composed of coarser lines of deposition, as is seen in figure A. This spore continues to elongate (fig. B), and very soon, through the formation of a series of three walls at right angles to the long axis, contains four cells (see fig. C). In most instances this division takes place after the spore is discharged. During the elongation of the spore the exospore wall increases in extent, for the distance between papillae increases and the rays of the "rosettes" spread (fig. C).



FIGS. A–J. Stages in the development of the leafy plant from the spore, in the genus *Ceratolejeunea*. FIGS. A–C, spores at about the time they are shed from the capsule. FIGS. D–E. The eight-celled thallus within the old exospore with its characteristic markings, and the partly developed secondary thallus (without markings) developed from the apical cell with two cutting faces. FIGS. F–G. Initiation of the apical cell with two cutting faces from a cell at the end of the thallus within the exospore. FIGS. H–J. Stages in the development of the sporeling including the early stages of the leafy shoot. Figures A–C, ×400; D–J, ×200.

These latter tend to become less conspicuous with the increase in the size of the protonema, and in its later stages are usually not noticeable (see figs. D–J).

Apparently the next stage is the formation of a wall more or less parallel to the long axis of the spore, in each of the four cells, so that an eight-celled thallus is formed. It is, of course, two cells broad and four cells long. This eight-celled filament can always be distinguished because of its papillose wall, the exospore. Sporelings which had reached this stage but had not developed beyond it could not be found.

The next stage was one in which an apical cell with two cutting faces had already developed from a cell of the eight-celled thallus. Figures F and G

show the initiation of such an apical cell. Through the activities of this apical cell two rows of segments are cut off, resulting in the formation of a secondary thallus, clearly distinguished by the smooth walls of its cells (figs. D, E).

Each of the segments cut off from the apical cell soon divides again by a wall more or less parallel to the long axis of the thallus; and in this way the secondary thallus becomes four cells broad. Figure H illustrates development to this point. The thallus within the old exospore is papillose; the remainder, the secondary thallus, is fully developed below, four cells broad, and near its tip shows several segments not yet divided, and the apical cell.

After a variable number of segments have been cut off, the apical cell becomes transformed into an apical cell with three cutting faces. This gives rise directly to a leafy shoot with no intermediate stages (see figures I and J).

The first leaves formed are of the primary type, small, ovate-lanceolate, and plane. These are followed by the larger, juvenile leaves with large water-sacs, which are usually accompanied by underleaves. The details of the leafy plants of individual species are discussed below.

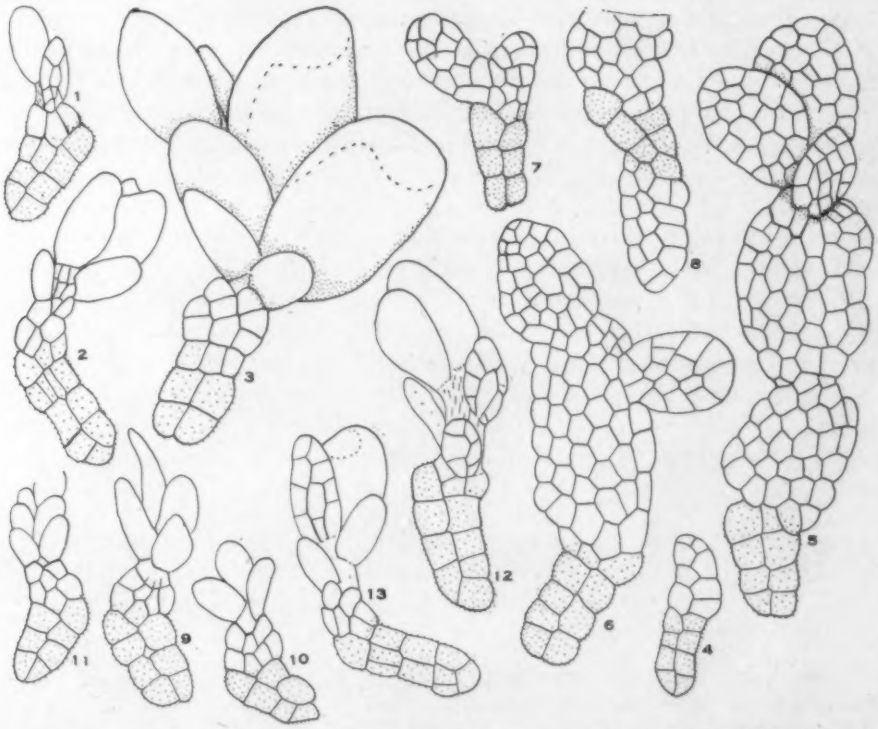
The above is a brief résumé of what I consider to be the pattern of development of the sporeling of the genus *Ceratolejeunea* (except for *C. guianensis*). Of course, many of the sporelings do not conform to this pattern in all of its detail, and I have attempted to illustrate the deviations in the discussion of individual species. This method tends to emphasize the exceptions rather than the more usual pattern of development, since the majority of the figures are examples of the deviations which were observed, while the majority of the sporelings conform to the basic pattern.

The grouping of the species is here based on the type of horns of the perianth, and the three species which follow have perianths with large, bulbous horns. However, *C. malleigera* is an aberrant species, since only two instead of the customary four horns are produced.

C. SPINOSA (G.) Steph. (Figures 1–3.) None of the few sporelings which were found had the broad, secondary thallus developed to any extent; in fact, in figures 1 and 2 it is scarcely suggested and in figure 3 is very poorly developed. The formation of additional walls in some of the cells of the thallus within the exospore, so that it becomes more than two cells broad as is shown in figure 2, is not uncommon. This figure also suggests the formation of a second apical cell and therefore a growing point, at the other end of the thallus. Spores in unopened capsules were too immature for detail of the spore wall, but they were papillose and the "rosette" pattern was suggested. Figure 3 illustrates a plant in which both primary and juvenile leaves had developed. It is curious that the three leaves on the left side of the stem are of the primary type, while two of the three on the right are of the juvenile

type, yet all of them developed from alternating segments of the same apical cell. No underleaves were observed.

C. MALLEIGERA (Spr.) Steph. (Figures 4–8.) These sporelings were among the fruiting plants of the original and only collection of the species. The eight-celled stage within the exospore was quite uniform in its development throughout, except that occasionally only six cells were formed. Development proceeds in the usual fashion (see figure 4 and the lower part of figure 8), except that the outer cell of the pair formed by each segment usually divides

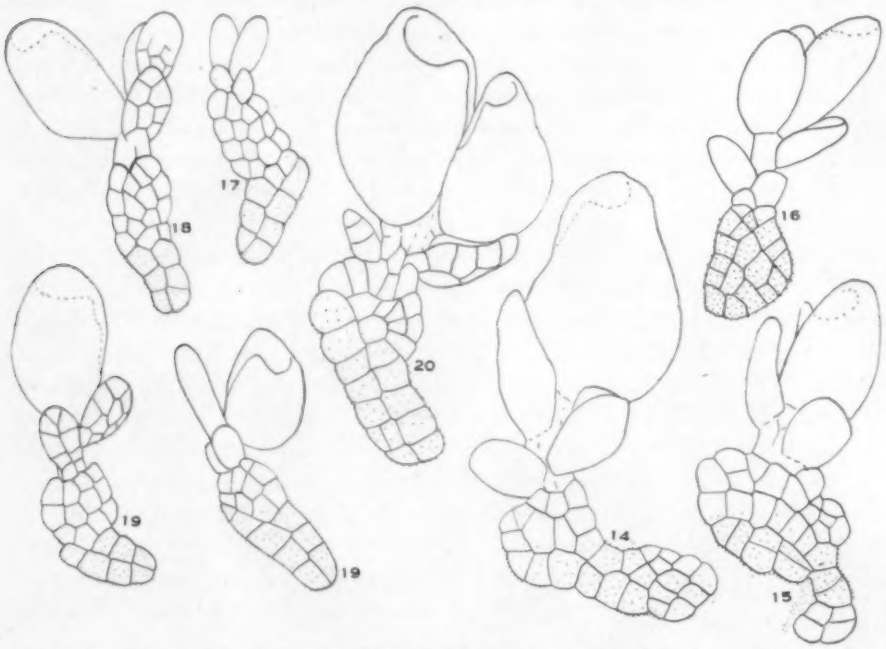


FIGS. 1–3. *C. spinosa* (G.) Steph. Figures 1–2 from Suringar, West Indies; figure 3 from *Breutel*, St. Kitts, the original. FIGS. 4–8. *C. malleigera* (Spr.) Steph., from the original, Bolivia. FIGS. 9–13. *C. plumula* (Spr.) Steph. Figures 9–10 from *Duss 44*, Guadeloupe, figures 11–13 from Spruce, Brasil. All × 200.

again so that the secondary thallus is six cells broad throughout most of its length. This development can be followed in detail in the upper part of figure 6. A striking example of a broad secondary thallus grown out from each end of the eight-celled thallus is shown in figure 8. Figure 5 illustrates the only example of the formation of leaves on sporelings of this species. They are all of the primary type. No underleaves are evident. Here also, growth of the broad secondary thallus was restricted for a time, then pro-

gressed after the usual pattern. Branching of the secondary thallus is not uncommon (see figures 6 and 7); the branch arises from a marginal cell.

The presence of a secondary thallus broader than that customary in the genus raises the question of the taxonomic position of the species, especially since the species is also unusual in that there are only two instead of four horns on the perianth, and the ocelli of the leaves are no larger than the leaf cells and are numerous and scattered throughout the leaf. In most of the species the ocelli are large, and from one to several in a basal position, or they form a nerve. Even with the differences mentioned above this species



FIGS. 14–16. *C. flagelliformis* (Steph.) Fulford. Figures 14–15 from *Evans*, Puerto Rico; figure 16 from *Duss 385*, Martinique. FIGS. 17–20. *Ceratolejeunea* sp. from the Mitten Herbarium, collected in Java. All × 200.

certainly resembles species of *Ceratolejeunea*, but its taxonomic position as a member of the genus might be questioned.

C. PLUMULA (Spr.) Steph. (Figures 9–13.) Spores in the immature capsule were densely papillose, and also suggested the "rosette" pattern of markings, but no free spores in the early stages of sporeling development were found. The older sporelings suggest very strongly those of *C. spinosa* described above. The thallus within the old exospore is clearly delimited, although more than eight cells are sometimes present (see figure 13). The broad secondary thallus is extremely limited and sometimes scarcely developed, as was the case in *C. spinosa* (compare figures 9 and 10 with figure 12).

The next two species are characterized by having the horns of the perianth extremely long, slender, and terete.

C. FLAGELLIFORMIS (Steph.) Fulford. (Figures 14–16.) Not more than half a dozen sporelings were seen; all of them were irregular in their development and did not conform well with the general pattern. In all examples the thallus within the exospore was very irregularly developed. The irregular cell plate formed within the exospore shown in figures 14 and 15 may well have developed from an eight-celled thallus, since these cells showed a remarkable capacity to divide; there is evidence of more than one growing point; and only a part of each thallus in question is covered by the old exospore. It is possible also that the development of the thallus shown in figure 16 could have come about in the same way. A rudimentary secondary thallus is to be seen in figures 14 and 15 but none is apparent in figure 16. The leafy stem develops in the usual manner.

CERATOLEJEUNEA sp. (Figures 17–20.) This unnamed material, collected in Java, is in the Mitten Herbarium at the New York Botanical Garden. The species is very similar to *C. flagelliformis*. The leaves have a "nerve" of ocelli. All of the many sporelings observed in this material exhibited the usual pattern of development (figs. 17–19). Figure 20 shows a plant with more than the usual number of cells in the thallus covered by the exospore, and with a secondary thallus broader than in the other specimens. This thallus suggests the irregular development which was seen in *C. flagelliformis*.

The following species belong to that large group within the genus in which the perianth exhibits no striking characteristics. The horns are of characteristic length or are developed as short knobs.

C. BREVINERVIS (Spr.) Evans. (Figures 21, 22.) Many examples of the early stages of development were observed, and the pattern conforms to that described earlier. Figures 21 and 22 present the usual picture. The secondary thallus is poorly developed in figure 22 but is somewhat larger in some of the examples not shown here. The leafy axis presents a difficult problem. At its base it bears a pair of primary leaves followed by a pair of larger juvenile leaves with their large water-sacs. These are followed on the left side of the stem by another primary leaf and then a juvenile leaf, but on the right side of the stem, above the first juvenile leaf are two leaves with small ventral lobes, more or less intermediate in form between primary and juvenile leaves, followed by another juvenile leaf. All of these leaves have developed from segments of the same apical cell. An underleaf occurs on the upper part of the stem.

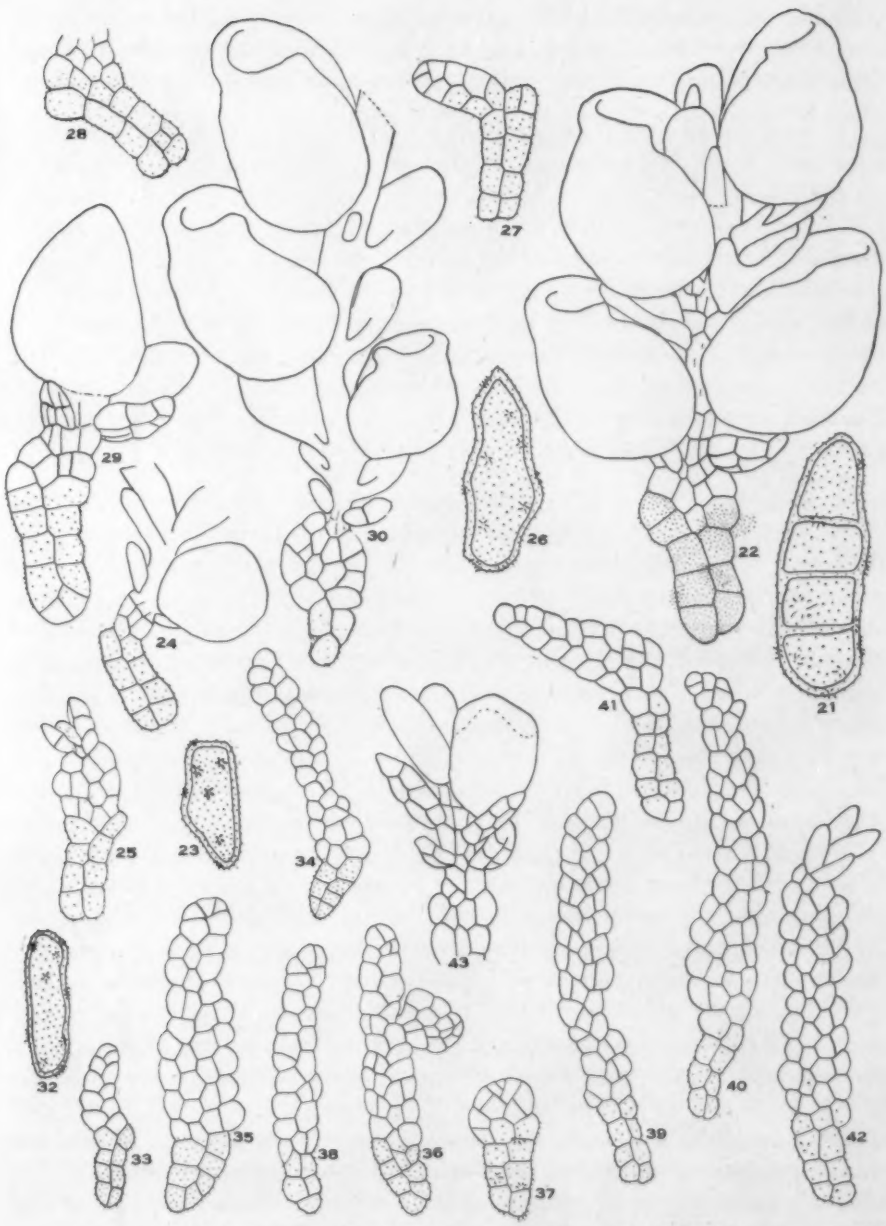
C. MARITIMA (Spr.) Steph. (Figures 23, 24.) These figures were drawn from plants collected by Spruce along the Amazon. They are from the spores of plants of the variant in which the leaf usually has a conspicuous "nerve" of large ocelli, and in which spherical lobules are for the most part absent. Plants of this character compose only one of several of the variants of the species which occur in tropical America.[5] Spores from within capsules not quite mature were papillose and showed, in addition, the "rosette" pattern of supplementary thickenings. The advanced sporelings were in a poor state of preservation but all of them showed the characteristic eight-celled thallus within the exospore, and also a poorly developed secondary thallus. Figure 24 is characteristic of the group.

C. GRANDIBRACTEOLATA Fulford. Figure 25 is from material collected by Spruce along the Rio Negro in Brazil. It is the only example of a sporeling of this species which was sufficiently well preserved to be illustrated. It conforms to the general pattern, with eight cells in the exospore, one end-cell of which has given rise to an apical cell with two cutting faces. This in turn gave rise to segments which have formed the secondary thallus four cells broad. After several segmentations the growth of the thallus was terminated through the development of the apical cell with three cutting faces which produced the leafy plant.

C. MEGALOPHYSA (Spr.) Steph. (Figures 26–30.) This species also exhibits the usual range of deviation in the various stages of the development of the sporeling. The spores are similar to those of the other species in shape and wall-sculpturing. Figure 28 shows supplementary growth and the probable initiation of a second apical cell during the eight-celled stage. A thallus in which an apical cell has developed at each end is shown in figure 29. In figure 30 the thallus which was developed in the old exospore is poorly represented, perhaps it never was developed in full, and the secondary thallus is short. This leafy plant also has an assortment of primary and juvenile leaves on both sides of the stem. Underleaves are absent.

C. CUBENSIS (Mont.) Schiffner. (Figures 32–36.) Large numbers of sporelings in the various earlier stages of development are present in the material but none of them had developed leafy shoots. The spore at about the time that it is shed from the capsule is similar to those of the other species, green, elongate, papillose, and with supplementary markings in the "rosette" pattern (see figure 32). The thallus developed within the exospore is uniform, i.e. always of eight cells, and rarely was a variation observed. The apical cell with two cutting faces forms the usual secondary thallus two cells broad

[5] **Fulford, M.** Studies on American Hepaticae—VI. Ceratolejeunea. To be publisehd in Brittonia.



FIGS. 21–22. *C. brevinervis* (Spr.) Evans, from *Evans 232*, Jamaica. FIGS. 23–24. *C. maritima* (Spr.) Steph. from *Spruce*, Amazon. FIG. 25. *C. grandibracteolata* Fulford, from *Spruce*, Brasil. FIGS. 26–30. *C. megalophysa* (Spr.) Steph. Figure 26 from *E. G. Britton, D. Coker, Rowland*, Trinidad; figures 27–30 from *Smith*, British Guiana. FIGS. 32–36. *C. cubensis* (Mont.) Schiffn. Figure 32 from *Mosén*, Brasil; figures 33–34 from *Br. Léon & Clement 5561*, Cuba; figures 35, 36 from *Ramon de la Sagra*, Cuba. FIGS. 37–43. *C. rubiginosa* Steph. from *Wright*, Cuba, the original. Spores, ×400; sporelings, ×200.

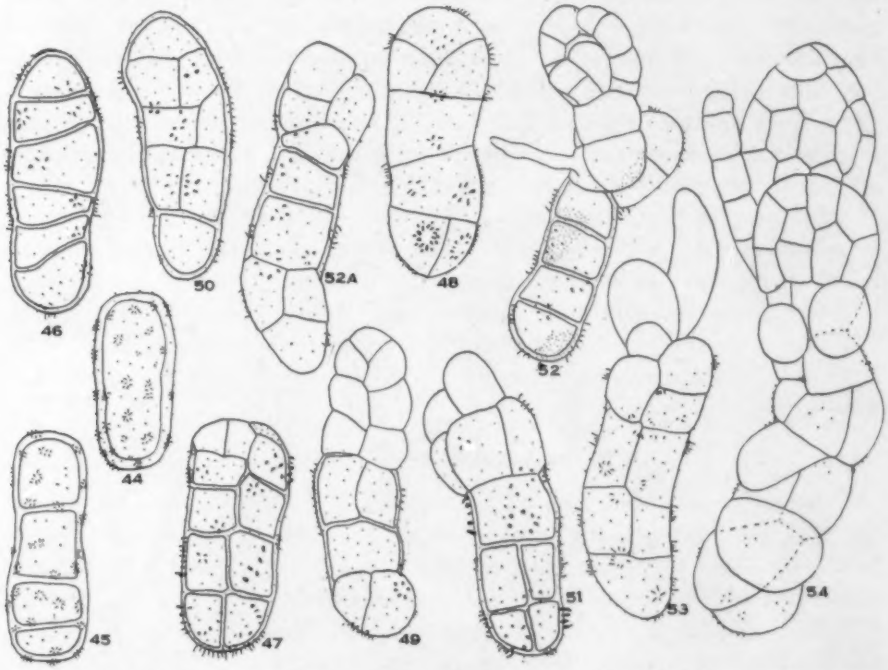
(fig. 33), which very soon through additional divisions of the segments becomes four cells broad (see figures 34–36). Branches are sometimes formed from marginal cells of the secondary thallus, as is indicated in figure 36.

C. RUBIGINOSA Steph. (Figures 37–43.) All of the drawings were from sporelings in the original material, collected by Wright in Cuba. This species closely resembles *C. cubensis* in habit and the sporelings also are very similar. They were present in great numbers and were remarkably regular in development. However, some of the usual deviations do occur; for example, less than eight cells in the exospore appear in figure 38, and an apical cell at each end of the eight-celled thallus is seen in figure 41. For the most part, the markings of the exospore are faint and scattered, but even the "rosette" pattern is present on some of the younger sporelings, as seen in figure 37. The first leaves formed on the shoot are of the primary type (figs. 42, 43), and are followed by the characteristic juvenile leaves (fig. 43).

C. GUIANENSIS (N. & M.) Steph. (Figures 44–54.) The sporelings of this species differ markedly from those described above for the other species of the genus. In addition, even the spores from one capsule may show a curious range of variation in their patterns of development. The spores are green, elongate, and have the markings characteristic of the genus at the time that they are shed from the capsule (fig. 44). After this a series of cross walls is formed, cutting off four cells as in the other species (fig. 45), or a variable larger number (fig. 46). It appears that either of two types of development may then take place in these filaments. Either a plate of cells two cells broad, four cells long, and one layer of cells thick may develop (fig. 47), as in the other species, or the filament may divide irregularly so that a slender, cylindrical mass of cells is formed (see fig. 50). Figures 47 and 50 were made from sporelings from the same capsule. In addition, a few of the sporelings had developed an apical cell with two cutting faces from one end of the thallus within the old exospore (figs. 48, 49), and in one of them a secondary thallus several cells long had been formed (fig. 49). None of the more mature sporelings which were observed showed an indication of such a secondary thallus. All of these older sporelings (25 or more from several capsules were studied), were of the types shown in figures 53 and 54, and those on which several primary leaves were well developed were similar to that illustrated in figure 54. Here a slender, cylindrical mass of cells develops within the old exospore and at one end of this the leafy shoot is formed. Figures 51–52a illustrate variations in which part of the thallus within the exospore is one layer of cells thick and part is several cells thick. They suggest transitional stages between the two modes of development. The thallus shown in figure 53 must have originated through earlier stages such as those illustrated in figures 45 and 47; while a thallus of the sort shown in figure 54 suggests earlier

stages like those illustrated by figures 46 and 50. The sporelings illustrated in figures 46, 47, 49, 50, 51, 52 and 52a came from one capsule. Here, the variations are certainly internal in origin, rather than the result of the influence of the environment. The material suggests that the cylindrical type of thallus is the final result of development within the old exospore, and that it may be arrived at through either of several patterns of development.

The discovery of a sporeling pattern in *C. guianensis* totally different from any yet observed in any other species of *Ceratolejeunea* tends to sug-



FIGS. 44–54. *C. guianensis* (N. & M.) Steph. FIG. 44. A spore from an immature capsule. FIGS. 45–46. Initial stages in cell division in the development of the sporeling. FIG. 47. An eight-celled thallus within the exospore similar to the condition found in the other species of the genus. FIGS. 48–49. Early stages in the development of the sporeling in which an apical cell with two cutting faces is formed at one end. FIGS. 50–52A. Variations in the development of the multicellular cylindrical thallus from one end of which the leafy plant develops. FIG. 53. A sporeling in which the thallus is one layer of cells thick except just below the leafy shoot. FIG. 54. A characteristic mature sporeling showing the slender cylindrical thallus and the shoot with well developed primary leaves. All magnifications, ×400. Nos. 46, 47, 49, 50–53 are from one capsule. Drawn from *E. G. Britton, Coker, and Rowland, 851,* Trinidad.

gest that the species has been incorrectly assigned to this genus. The absence of well developed horns on the perianth might also be used as an argument in favor of this line of thought. On the other hand, the fact that in at least some of the capsules, sporelings occur which follow, in the earlier stages at

least, the plan of development observed in other species of the genus (an eight-celled thallus stage in the exospore in figure 47, and a secondary thallus with an apical cell with two cutting faces in figure 49), causes one to question such a conclusion. With only our present information there can be no decisive answer.

Of the 12 species discussed above, ten of them indicate a common basic pattern of sporeling development. The remaining species, *C. malleigera* and *C. guianensis*, in addition to a difference in the sporelings, also have other characters which to a greater or lesser degree are at variance with the characteristics of the genus *Ceratolejeunea*. Both species also have some vegetative characteristics which are definitely of the *Ceratolejeunea* category. Such species present a difficult and puzzling problem to the taxonomist, and the discovery of sporeling patterns different from that of the other species of the genus only adds to the difficulties involved.

Our knowledge of the sporelings, together with their patterns of development and range of variation, in the other genera of the family *Lejeuneaceae* is still too meagre to be of assistance in the interpretation of the puzzling problems presented within the genus *Ceratolejeunea*. The results to the present time indicate, however, that within limits these patterns do serve to show relationships and therefore can be of service in both taxonomic and phylogenetic interpretations.

2. VEGETATAVE REPRODUCTION

Vegetative reproduction has been mentioned in the genus by Evans[6] (p. 277), who states that it is not unusual for a leaf cell to give rise directly to a leafy shoot or propagulum without the interpolation of a protonemal structure; and by Degenkolbe[7] who quotes Evans (p. 59), and later lists *Ceratolejeunea* as having two records of brood bodies of the thallose form (p. 89). He does not describe or figure these structures.

Vegetative reproduction from ordinary leaf cells was seen in eight of the species studied. Except for *C. caducifolia* the phenomenon was of infrequent occurrence, and in many of the species only one or two examples have been observed, although a quantity of material has been examined. Except in *C. caducifolia* the leaves on which they occurred were attached to the stem.

The story of development of the new plants in all of the species except *C. caducifolia* is briefly as follows. An apparently mature cell of a leaf dedifferentiates and bulges, usually on the dorsal surface. Then, through the formation of a wall, in optical view at right angles to the long axis of the

[6] **Evans, A. W.** Hepaticae of Puerto Rico. V. Ceratolejeunea. Bull. Torrey Club 32: 273–290. *pl. 19, 20.* 1905.

[7] **Degenkolbe, W.** Brutorgane bei beblätterten Lebermoosen. Ann. Bryol. 10: 43–96. *f. 1–112.* 1937.

cell, two cells are formed. Further divisions in these bring about the formation of an apical cell with three cutting faces, which initiates the formation of the leafy plant. Rounded, undifferentiated cells are always present in greater or lesser numbers around the base of the stem. These cells were

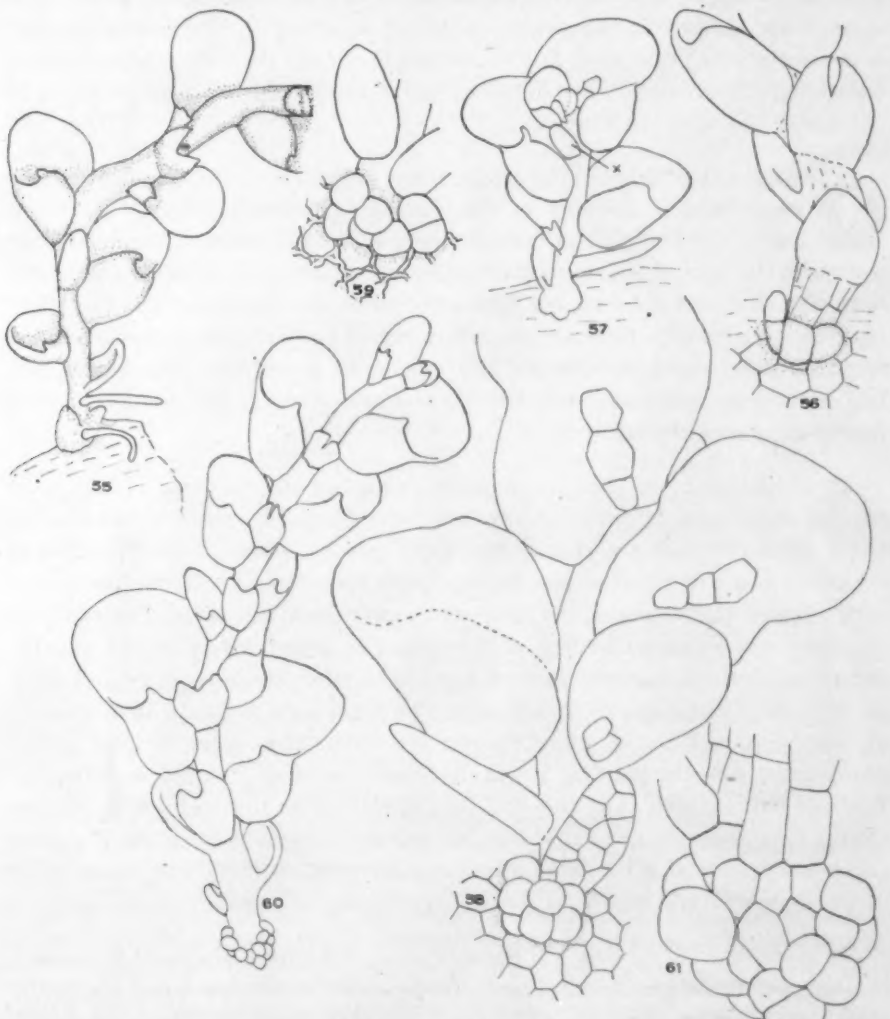


FIG. 55. *C. spinosa* (G.) Steph. Ventral view of a young plant, ×90, from *Evans*, Puerto Rico. FIG. 56. *C. flagelliformis* (Steph.) Fulford. Ventral view of a young plant, ×400, from *Brenes 19066*, Costa Rica. FIGS. 57–61. *C. maritima* (Spr.) Steph. FIG. 57. Ventral view of a young plant, – X the underleaf, ×90. FIG. 58. Dorsal view of the same plant, ×200. FIG. 59. Detail of the base, ×400. FIG. 60. Ventral view of a plant ×90. FIG. 61. Detail of the base, ×400. Figures 57–59 from *Mosén 266*, Brasil; figures 60–61 from *Duss 634*, Martinique.

formed through several divisions of the first pair of cells from the original leaf cell, but they did not become a part of the structure of the stem.

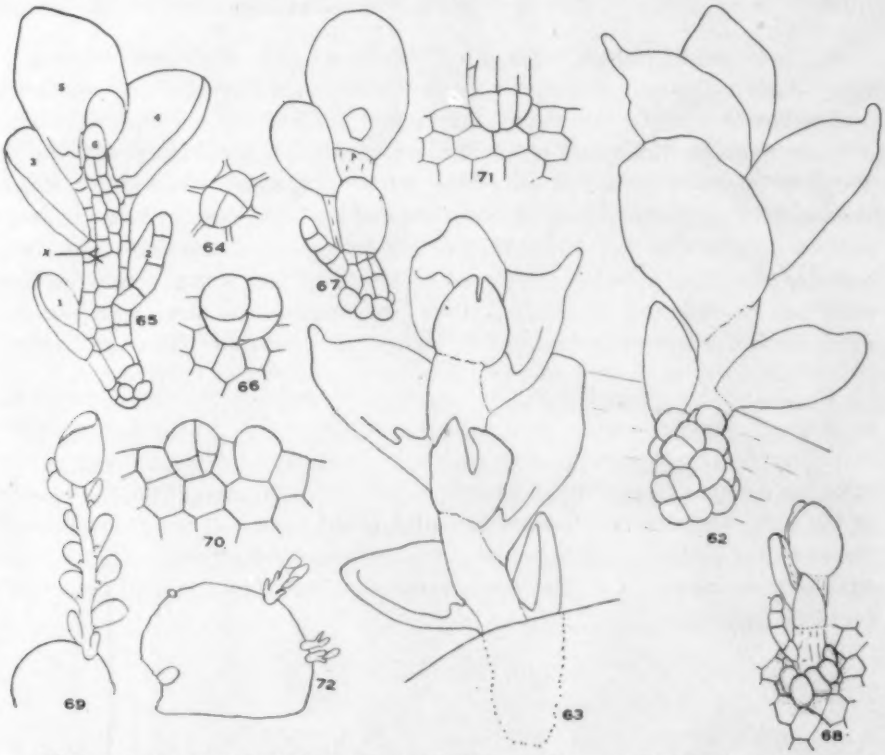
Leaves of the primary type usually precede the formation of the small leaves with ventral lobes. So long as only one row of ventral cells is formed from the ventral segment, no underleaves develop; but they make their appearance soon after two ventral rows are established. The first underleaf is in most plants undivided, but stems on which only the bifid type occur are occasionally met with. More detail of the development can best be brought out under the individual species.

C. SPINOSA (G.) Steph. (Figure 55.) The figure represents the only example of regeneration observed in this species. The shoot originated on the dorsal side of the leaf and had become very long. A number of rounded cells surround the base of the stem, and two rhizoids have been produced near the base. The first leaf suggests the primary leaf of the sporeling, but the other leaves suggest the pattern of the adult leaves rather than juvenile leaves, since the water-sac is less than half the size of the dorsal lobe. The first underleaf is elongate and undivided, but the rest are orbicular and bifid and more nearly approach the adult type.

C. FLAGELLIFORMIS (Steph.) Fulford. (Figure 56.) Several examples of regeneration were found in a collection of this species made by Brenes in Costa Rica. The species characteristically produces numerous flagelliform branches, some of them so slender and with leaves so greatly reduced that they suggest the shoots which have developed from leaf cells. The position of origin will at once distinguish the two. The larger leaves of the flagelliform branches are coarsely toothed, but the smaller ones are entire and similar to those of the stems from leaf cells. The plant seen in figure 56 developed on the dorsal surface of a leaf from a cell with thick walls, located half a dozen cells from the margin. From the ventral surface it could be seen that this cell had divided into two and that one of these new cells had divided again. Very few rounded cells were formed at the base of the stem. The first underleaf is undivided but the later ones are bifid. Some of the leaves were of the primary type, plane, others had water-sacs of one sort or another.

C. MARITIMA (Spr.) Steph. (Figures 57–61.) Figures 57–59 show the sort of plant produced in regeneration in that variant of the species in which the leaves are characterized by a "nerve" of large ocelli. Plants of this sort apparently regenerate more readily than those of the other variations of the species, for the new plants were present in many of the collections. They are always robust, with the basal rounded cells fairly numerous and conspicuous. The first leaves are of the primary sort (figs. 57, 58); they are followed by leaves with large water-sacs but which are less saccate than the juvenile

leaves. Three of these leaves show the row of ocelli. The first underleaf is undivided. Figures 60 and 61 illustrate a plant produced through regeneration in another of the variants of the species, one in which ocelli are solitary or in pairs and basal. This plant is very similar to that shown in figures 57 and 58 except that the first underleaf is bifid. The first underleaf of other



FIGS. 62, 63. *C. patentissima* (H. & G.) Evans. FIG. 62. Dorsal view of a young plant, ×200. FIG. 63. Ventral view of the same plant, ×200. From *Stehle 3638b*, Martinique. FIGS. 64, 65. *C. cornuta* (Lindenb.) Steph. FIG. 64. Mature leaf cell which has gone through two divisions on the way to the formation of a new plant, ×400. FIG. 65. Ventral view of a young plant, ×200. From *Fendler*, Trinidad. FIGS. 66, 67. *C. guianensis* (N. & M.) Steph. FIG. 66. An early stage in regeneration, ×400, from *Small, Mosier and Small 6158* in Florida. FIG. 67. Dorsal view of a young stem, ×200, from *Britton & Shafer 1724* in Puerto Rico. FIG. 68. *C. cubensis* (Mont.) Schiffn. Dorsal view of a young plant, ×200, from *Evans 348*, Jamaica. FIGS. 69–72. *C. caducifolia* (Spr.) Steph. FIG. 69. Ventral view of a young plant, ×90. FIG. 70. Portion of the margin of a leaf with two cells in early stages of regeneration, ×400. FIG. 71. Detail of the base of a shoot on the margin of a leaf, ×400. FIG. 72. A leaf with four marginal shoots, ×90. From *Spruce*, Manáos, Brazil.

shoots on different leaves was undivided. Figure 61 shows that here, as in the other plants, a distinct group of rounded cells is developed at the base of the new shoot.

C. PATENTISSIMA (H. & G.) Evans. (Figures 62, 63.) Figures 62 and 63 show both the dorsal and ventral views of the only example which was seen. The rounded basal cells are numerous. Most of the leaves are pointed, a character not observed in the young plants of the other species. All the leaves show some development of a ventral lobe. All the underleaves are definitely bifid.

C. CORNUTA (Lindenb.) Steph. (Figures 64–65.) Figure 64 shows an early stage in the development of a new shoot from a leaf cell. The enlarging leaf cell has bulged on the dorsal surface and divided twice. Figure 65 shows a young plant in which only a few of the rounded, basal cells were developed. Three of the leaves, nos. 1–3, are of the primary type and nos. 4 and 5, which follow, give an indication of the development of the ventral lobe. It is of interest to note that up to the point of the formation of the third leaf, only one row of ventral cells has developed (see x in fig. 65), but at this point two rows can be observed. It is after these two longitudinal rows have become established that an underleaf, no. 6, makes its appearance. It is undivided.

C. GUIANENSIS (N. & M.) Steph. (Figures 66 and 67.) Figure 66 shows an early stage (but somewhat later than that of figure 64), in the development of the new shoot. Figure 67 shows a leafy plant. The leaf at the top of the stem has a single large ocellus. Few rounded cells were developed at the base of the stem. Other larger plants in which there were half a dozen pairs of leaves of the primary and juvenile types were occasionally seen. These were similar to the shoots of *C. maritima* except that very few rounded cells were formed at the base.

C. CUBENSIS (Mont.) Schiffn. (Figure 68.) Regeneration is not uncommon in plants of this species. Most of the shoots were small, and had produced only a few leaves, of the primary type. Rounded cells are conspicuous at the bases of the shoots. Figure 68 is representative. It suggests the shoots of *C. cornuta* and *C. guianensis* shown in figures 65 and 67.

C. CADUCIFOLIA (Spr.) Steph. (Figures 69–72.) Regeneration in this species is somewhat different from that in those just described, since the new plants usually arise from the marginal cells of the leaves. A cell bulges beyond the normally crenulate margin (see figure 70). Next a wall at right angles to the margin and to the plane of the leaf divides the cell into two (fig. 70). Most of these cells again divide at right angles to the first wall and to the plane of the leaf (fig. 70). The next divisions initiate the formation of an apical cell with three cutting faces. Through the activities of this cell the leafy plant is developed. Every cell formed through the early divisions of the marginal cells becomes a part of the stem, and there are no rounded, undifferentiated cells at the base of the stem as there are in the other species.

The leaves of the new plant all give some indication of a ventral lobe (fig. 69). In some of the stems which were examined there is only one row of cortical cells developed from the ventral segment, and underleaves are absent. Some of the new shoots were very long and some of these developed juvenile leaves for a time, so that a stem often shows a variety of leaves (see figure 69). No underleaves were observed.

In all these species the pattern of development of a new shoot from a leaf cell through regeneration is more or less uniform. The development in *C. caducifolia* is somewhat different, but only in that the new shoots usually arise from cells of the margin rather than from the interior of the leaf. This same pattern of regeneration also occurs in *Frullania Asagrayana, Leucolejeunea clypeata*, etc., and thus appears to be of little significance as an aid in the taxonomy of the genus or the species.

SUMMARY

1. Sporelings

1. Sporelings of twelve species of *Ceratolejeunea* have been studied.

2. The sculpturing of the spore coat was similar in all of the species, and like that of several of the other genera of the *Lejeuneaceae*. The exospore is papillose with additional thickenings in the form of scattered "rosettes."

3. The sporelings show a fundamental basic pattern of development which may well be designated the *Ceratolejeunea* type. In this, a thallus two cells broad and four cells long is formed within the exospore. An apical cell with two cutting faces develops from one of the cells at the end, and the segments cut off from it form the secondary thallus which becomes four cells broad and of indefinite and variable length. Eventually, the apical cell of this thallus becomes transformed into an apical cell with three cutting faces and the leafy axis is formed through its activities. In *C. malleigera* and *C. guianensis* exceptions to this pattern occur.

4. There is some variation among the sporelings of a single species:

a. Variations of the thallus within the exospore take the form of fewer cells; or of more cells, which are formed through the division of one or more of the original eight cells; or of a second apical cell at the opposite end.

b. Variations of the secondary thallus have to do primarily with its length and less often with its width. Often it is only one or two cells long when the leafy plant is formed. Branching from marginal cells is not uncommon.

5. The leafy stem develops at the growing tip of the secondary thallus. The first leaves are of the primary type and are followed by the leaves with large water-sacs, the juvenile leaves.

6. The pattern of development of the sporelings appears to be constant within the genus (when *C. malleigera* and *C. guianensis* are excepted), and

may be used to advantage in the taxonomic study of species whose position has been regarded as doubtful.

7. *C. malleigera* may be considered an aberrant species, for only two horns are developed on the perianth and the secondary protonema of the sporeling is six cells broad instead of four.

8. *C. guianensis* exhibits a mature sporeling of entirely different pattern from that of the other species studied. It is long, slender, and cylindrical. Whether this difference should be regarded as significant in relation to the taxonomic position of the species cannot be demonstrated at the present time.

9. There is every indication from this study that sporeling patterns can be of assistance in generic determinations; and that a knowledge of these patterns will aid materially in the reconstruction of phylogenetic relationships.

2. Vegetative Reproduction

10. The single leaf cell which gives rise to the new plant is totipotent.

11. The cell bulges (usually on the dorsal surface of the leaf), and after several divisions an apical cell with three cutting faces is formed. In most species some of the early cells formed divide several times more and remain as a collar of rounded, unspecialized cells at the base of the stem.

12. The first two leaves formed are usually of the primary type, and those which follow are usually of a modified adult form. Juvenile leaves occur only occasionally.

13. Usually only one vertical row of cortical cells from the ventral segment occurs on the lower part of the stem. It is only after two rows become established that the underleaves are formed.

14. The first underleaf of most new plants is undivided, the later ones are bifid.

15. The pattern of development of the new shoots of *C. caducifolia* differs from that of the other species in that each arises from a marginal cell, and no supplementary rounded cells are formed at the base of the stem.

I wish to express my appreciation to Dr. A. W. Evans who has given generously of his time in reading the manuscript and in making suggestions and criticisms; to Dr. H. W. Rickett for helpful suggestions; and to the New York Botanical Garden for the use of the Library and the Herbarium and for facilities for work.

University of Cincinnati
and
The New York Botanical Garden

BULLETIN OF THE TORREY BOTANICAL CLUB
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A NEW PARASITIC RED ALGA FROM SOUTHERN CALIFORNIA

ELMER YALE DAWSON

Kylin[1] recognizes three parasitic genera in his monograph of the Delesseriaceae: *Gonimocolax*, *Polycoryne*, and *Gonimophyllum*, all of which are arranged as members of the Nitophylleae. *Gonimophyllum* is placed in the Cryptopleura Group because the gonimoblasts bear terminal carpospores, while the other two genera are placed in the Myriogramme Group in which the gonimoblasts bear carpospores characteristically in chains. All three genera lack growth from an apical cell, except in young stages, and intercalary division of the primary cell row is typical.

A new and very distinctive parasitic genus, *Loranthophycus*, is described below, distinguished from the other parasitic Delesseriaceae by its mode of growth from an apical cell, and by the absence of intercalary division of the primary cell row. The divisions of the apical cell are not limited to young stages, but continue through the entire growth of the thallus. Although this is not yet confirmed by studies of cystocarpic plants, from the evidence at hand *Loranthophycus* seems to be a degenerate member of the Membranoptera Group of the Delesserieae in which (1) growth is from an apical cell, (2) tertiary cell-row initials do not reach the thallus margin, and (3) intercalary division of the primary cell row is absent.

Loranthophycus Dawson, gen. nov.

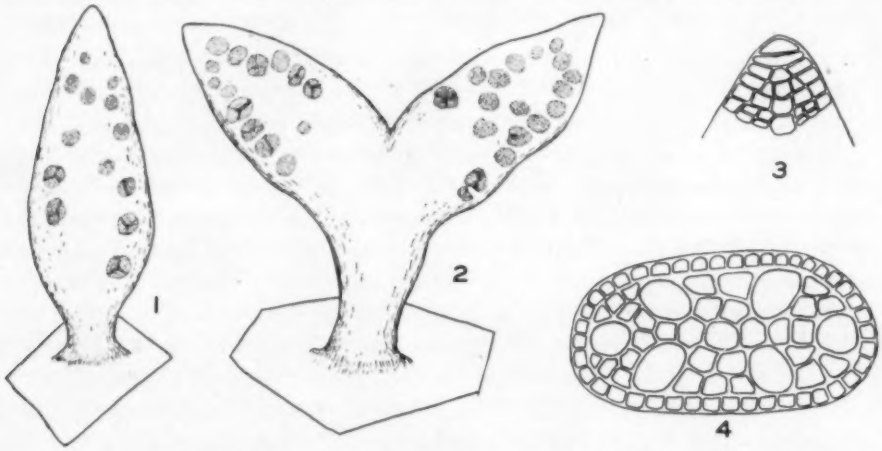
Thallus minutulus, parasiticus, dilute roseus; partibus fertilibus e pulvino humili in hospite, lanceolatis, compressis, brevistipitatis, cellula apicali sine divisionibus cellularum intercalarium in primario ordine crescentibus; cellula prima tertii ordinis non in margine posita; tetrasporangiis tripartitis, per totam frondem sparsis; cystocarpiis antheridiisque nondum visis.

Plants minute, parasitic; fertile thalli pale rose-colored, arising from a very low, inconspicuous, cushion-like point of union with the host, lanceolate, compressed, with a short stipe; growth from an apical cell which cuts off a thin, saucer-shaped cell basally, this soon divided by two inclined lateral walls to set off the initials of the primary (central) and secondary cell-rows; secondary cell-row initial remaining at frond margin; tertiary cell-row initials not reaching margin; lateral divisions to form pericentral cells beginning very near the apex; intercalary division of primary cell row absent; tetrasporangia tripartite, borne abundantly throughout the expanded part of the fertile thallus beneath the small-celled surface layer; cystocarps and antheridia unknown.

[1] **Kylin, H.** 1924. Studien über die Delesseriaceen. Lunds Univ. Årsskr. II. Afd. 2. 20: 1–111.

Loranthophycus californicus Dawson, sp. nov. (Figs. 1–4.) Frons brevistipitate, plerumque sola e strato basilari pulvinato, circiter 1 mm. alta; laminis lanceolatis compressis, integris, simplicibus aut bifurcatis, circiter 400 μ latis, 200 μ crassis; tetrasporangiis per totam frondem sparsis, maturi 90–100 μ diam.; cystocarpiis antheridiisque nondum visis.

Fertile fronds usually arising singly from the basal cushion, about 1 mm. long, lanceolate, compressed, acute above, narrowed below to a short, thick stipe; blades entire, simple or commonly forked, sometimes 3-lobed, the segments about 400 μ broad, 200 μ thick, of several layers of cells; surface cells 16–20 μ broad in surface view, forming an even epidermal layer; medullary cells 25–35 μ in greatest diameter; tetrasporangia scattered throughout the expanded frond in the outer medulla beneath the epidermis; mature quartets of tetraspores 90–100 μ in diameter; cystocarps and antheridia unknown.



FIGS. 1–4. *Loranthophycus californicus* Dawson. FIG. 1. A mature, simple tetrasporic plant. ×50. FIG. 2. A mature, forked tetrasporic plant. ×50. FIG. 3. Median optical view of the growing apex showing apical cell. ×350. FIG. 4. Cross section of mature tetrasporic frond showing tetrasporangial cavities. ×100.

TYPE: Parasitic on sterile fronds of an undescribed delesseriaceous plant dredged from rocky bottom at a depth of 25 meters off Point Loma, San Diego County, California, March 10, 1944. Deposited in the Herbarium of the University of California.

Loranthophycus californicus has been noted in but a single collection in which tetrasporic plants alone occurred in great abundance. A study of cystocarpic plants, therefore, may be expected to demonstrate more precisely the relationships of this peculiar plant.

Since most parasitic algae are limited to a single host and usually belong to the same family as does the host, the present inability to give specific identity to the plant upon which *Loranthophycus californicus* grows is not entirely satisfactory. It seems clearly delesseriaceous in structure, however, and vegetatively fits very nicely in the austral genus *Platyclinia* alongside

of *P. Crozieri*. The plant may, indeed, prove to be an undescribed boreal genus closely related to *Platyclinia*. For purposes of identification the following brief characterization is given.

Fronds erect, to 12 cm. high, membranous, rose-colored, attached firmly to rocks by means of a thin, adherent crust augmented by a few, short, clasping stolons, expanded from a branched, subterete stipe 1.0–1.5 cm. high; blades 3–4 from each main stipe, narrowly cuneate for 1.5–2.0 cm. above the point of branching, then expanding abruptly into a thin, smooth, veinless, narrow ovate, membranous portion 3–4 cm. broad, this usually simple, but sometimes dividing above the middle into two broad lobes; margins irregularly shallowly lobed or simply undulate; membranous parts with an external layer of small, flattened, pigmented, squarish cells and several irregular, medullary layers of large, colorless, thin-walled cells.

Acknowledgment is due to Dr. Martin W. Johnson who collected the type specimens.

SCRIPPS INSTITUTION
LA JOLLA, CALIFORNIA

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A NEW MONARDA (LABIATAE) AND A NEW CALOCARPUM (SAPOTACEAE) FROM MEXICO

CHARLES LOUIS GILLY

From collections made in various parts of Mexico during the year 1943, by members of a group on leave of absence from or associated with the New York Botanical Garden, the two entities below are selected as being worthy of description.

Monarda malloryi Gilly, sp. nov. Herba perennis; caule simplici vel ramoso; foliis serratis, supra glabris, subtus strigilloso-hirsutis ad venas, e deltoideo-lanceolatis ad deltoideo-ovata; foliorum laminis maximis 5.5–7.0 cm. longis, 2.4–3.0 cm. latis; calycibus 8–12 mm. longis, glabris, in ore dense hirsutis; corolla rubra vel rubro-magenta, 23–34 mm. longa, ore 3–4 mm. lato; staminibus sub ore corollae 3–4 mm. insertis.

Perennial herbs to at least 1.2 m. tall; stems simple or branched, glabrous to sparsely hirsute particularly on the angles and at the nodes. Leaves deltoid-lanceolate to deltoid-ovate, serrate (the teeth 3–6 mm. apart), glabrous on the upper surface, glabrous beneath except for sparse strigillose-hirsute pubescence on the veins, the largest 5.5–7.0 cm. long and 2.4–3.0 cm. wide, broadest 6–10 mm. above the base, scarcely more than one-half as long as the internodes which they subtend; median petioles 5–10 mm. long. Glomerules of the inflorescence solitary at the apices of the main stem and branches (when these are present), 1.5–3.0 cm. in diameter excluding the corollas; subtending bracts foliaceous, red-tinged or completely red on the upper surface, pale green beneath, glabrous above and below except for the strigillose-hirsute veins below, deltoid-lanceolate to lanceolate-elliptic, sub-petiolate, the larger 2.5–4.0 cm. long and 1.2–2.8 cm. wide. Calyces 8–12 mm. long, glabrous externally, the orifice densely hirsute; calyx-teeth 1–1.5 mm. long, glabrous or minutely pubescent but not glandular. Corollas crimson to crimson-magenta, sparsely pubescent with crisp hairs, 2.3–3.4 cm. long, 3–4 mm. broad at the throat, the constricted portion of the tube 8–14 mm. long. Stamens attached 3–4 mm. within corolla throat, exceeding the galea by 3–6 mm.; filaments glabrous, 12–15 mm. long; anthers 3 mm. in length. Style glabrous, exserted 3–8 mm. beyond the galea.

TYPE: MEXICO—Veracruz: near Piletas, July 14, 1943, *Donald Dodds 105* (NY). Probably also referable here are *Purpus 6048*, *Plunkett s. n.*, and *Leibmann 15583*, from the same general area, which have been doubtfully referred to *M. Pringlei* Fernald by McClintock and Epling (Univ. Calif. Publ. Bot. **20**(2): 161. 1942).

The species is named in honor of Dr. Lester Dewitt Mallory, Agricultural Attaché of the U. S. Embassy in Mexico City, whose co-operative interest has been of utmost value in furthering recent collecting in Mexico. Although most closely allied to *Monarda pringlei* Fernald of Nuevo León and Coahuila, and exhibiting certain tendencies toward *M. bartlettii* Standley of Tamaulipas, this entity—which should be an interesting garden subject wherever it can be grown—definitely merits specific recognition.

Calocarpum huastecanum Gilly, sp. nov. Arbor lacticifera; foliis subcoriaceis, supra atroviridibus subtus pallido-viridibus, glabris praeter petiolos et venulos subtus permanenter brunneo-tomentosos; laminis oblanceolatis vel anguste obovatis; floribus pedunculatis, fasciculatis vel solitariis; bractis floriferis lanceolatis ad lato-orbicularibus; perianthio luteo-albo, lobis quadrato-ellipticis; antheris et perianthii lobis subaequalibus; staminodiis staminodiorum filamentis consimilibus; ovario in anthesi conico pubescenti; fructu ignoto.

Tree with soft wood and milky sap to at least 30 m. in height and with stem to 1 m. in diameter. Leaves clustered at the apices of branches, subcoriaceous, dark glossy green above, pale green beneath, glabrous except for the petiole and the veins beneath which are densely and persistently brown-tomentose; leaf-blades oblanceolate to narrowly obovate, acuminate at the apex, 20–35 cm. long and 4–7 cm. wide; petioles stout, terete, 2–5 cm. long. Flowers solitary in axils of leaves of the season and grouped in small clusters above the old leaf-scars, shortly pedunculate, the stout peduncles 1–3 mm. in length. Floral bracts (which simulate an imbricated calyx) 5–8, minutely tomentose, yellowish-green with brown margins, entire, emarginate or erose at the apices, the outermost minute and lanceolate, the innermost broadly orbicular and to 4.5 mm. long and 5 mm. wide. Perianth subfleshy, 5-lobed, pale yellowish-white, 6–9 mm. in length and to 10 mm. in diameter at anthesis, the lobes spreading, quadrate-elliptic, rounded to almost truncate at the apices, 3–4.5 mm. long and 2.5–3.5 mm. wide. Stamens 5, attached at the summit of the perianth-tube opposite the lobes, equaling or slightly exceeding them in length; anthers narrowly sagittate, 1–1.5 mm. long. Staminodes subfleshy, terete, acute, 1–2.5 mm. long, resembling the filaments of the stamens and attached between the lobes of the perianth. Ovary at anthesis 2–3 mm. in diameter, conical, multi-ribbed, short-pubescent; style glabrous or sparsely minutely pubescent, apically truncate, 3–5 mm. long. Fruit not definitely known; said by natives of the area to be ovoid-globose, blunt at the apex and about 12–15 cm. long.

TYPE: MEXICO—San Luis Potosí: north of Tamazunchale at Km. 387 on the Laredo–Mexico City highway, July 14, 1943, *C. L. Gilly and H. W. Rickett 12* (NY).

The specific name is based on the common native geographical designation of the area towards the western margin of which the type was collected. The species differs from the other known species of the genus in Central America and Mexico principally by the persistent ferrugineous pubescence of the leaves, by details of the flower structure and, possibly, in the size and shape of the fruit.

NOTE: Since this paper was submitted for publication I have received a communication from Dr. C. L. Lundell, of Southern Methodist University, who observed the tree—from which the type was obtained—on November 6, 1943. He writes: "The small ovoid fruits were scarcely more than two inches long." Whether the fruits had at that time attained their mature size is not definitely known.

MEXICO, D. F.

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THE FERNS OF GILGIT, BALTISTAN, AND LADAK

RALPH R. STEWART

Most of the region covered by this paper is north of the Indus River and comprises the northernmost part of the British Indian Empire. It is north of the main Himalayan chain; the chief mountains are the Karakorums. Renato Pampanini (1930) in *La Flora del Caracorum* lists only five ferns and two species of *Equisetum*. I have visited parts of this region, and have obtained records of 25 additional ferns from this little known part of Central Asia.

The Karakorum Mountains form a massive barrier with passes 18,000 feet or more in height, shutting off practically all intercourse between Kashmir and the territory to the north. In this region are the largest glaciers outside of the arctic and here is to be found Mt. Godwin Austen, the second highest mountain in the world.

Gilgit, or more correctly, the Gilgit Agency, is just west of Baltistan and outside of Kashmir proper. The Gilgit Cantonment is a little less than 5000 feet in altitude and much lower than the rest of the area, which is very high and extremely rugged.

Ladak and Baltistan are the two chief divisions of the country to the north of the main range of the Himalayas in Kashmir State. They are both drained by the Indus and its tributaries. In the *Flora of British India* (Hooker 1872–1896) this region is called Western Tibet. Baltistan used to be called Little Tibet. In this paper the Deosai region south of Skardu is included in Baltistan, and Dras as part of Ladak.

The Indus at Skardu, the chief village in Baltistan, is about 7600 feet above sea level, while at Leh, the capital of Ladak, it flows at 11,000 feet. The whole country is mountainous. There is very little rain; the average at Leh is 2.7 inches a year. There is, however, much snow, which falls in the winter on the high mountains. There is little rain or snow in the main valleys. It is not a good country for ferns and none of the ferns in this list is abundant except *Cystopteris fragilis*. There are no real forests but in favorable places juniper forms trunks of good size without attaining much height.

Little work has been done on the ferns of Kashmir and the territory to the west. In the *Journal of Botany* for 1896 C. W. Hope published a list of 27 ferns which had been gathered by Gen. W. Gatacre on the Chitral Relief Expedition. Chitral is on the Afghan frontier southwest of Gilgit. His report includes a few ferns from lower levels. Most of the ferns here recorded grow at altitudes of from 8000 to 12000 feet, while a few grow even higher. They are chiefly temperate or alpine forms, except for *Ceterach officinarum* and

Cheilanthes persica, which are Mediterranean ferns growing at the eastern extremity of their range in the hot, dry, Indus valley.

The most useful work for those interested in the ferns of North India is C. W. Hope's "Ferns of Northwestern India," published in parts in the *Journal of the Bombay Natural History Society* from 1899 to 1904. Many of the records which follow are to be found in this work.

In spite of the inaccessibility of the region it has been visited by a good many explorers, beginning with William Moorcroft in 1820. Pampanini (1930) gives an excellent list of the visitors who collected plants, together with a bibliography and an account of the routes followed. The only omission I notice is the failure to mention the name of J. E. Winterbottom in connection with the Tibetan Boundary Delimitation Commission of 1847–1848.

Most of the specimens mentioned are in the Dehra Dun Herbarium of the Imperial Forestry Research Institute in North India and in the Royal Botanic Gardens at Kew. Many of them are in the Gordon College Herbarium at Rawalpindi in North Punjab.

I have omitted *Equisetum diffusum*, which I reported from Ladak in 1917, for I now consider it to be *E. arvense*. According to Pampanini, Wallich had a specimen of *Pteris longifolia* (*vittata*), which Moorcroft gathered in Ladak. I suspect an error, for no one else seems to have found it above 6500 feet. It grows farther down the Indus near Mt. Nanga Parbat in the hot zone.

OPHIOGLOSSACEAE

Botrychium lunaria (L.) Sw. Karakorum Mts., *Clarke;* W. Tibet, *Falconer*.

POLYPODIACEAE

Cystopteris fragilis (L.) Bernh. The only fern common throughout, from 7000 to 14000 feet.

Dryopteris Blanfordii (Hope) C. Chr. Baltistan, 12000–13000 feet, *Duthie*. Cited by Hope.

Dryopteris odontoloma (Moore) C. Chr. Gilgit, in 1847, 10000 feet, *Winterbottom*. Cited by Hope.

Dryopteris ramosa (Hope) C. Chr. Dras Valley, 10000 feet, *Duthie* 11677.

Dryopteris barbigera (Moore) Kuntze. Mitsahoi, Ladak Road, 11000 feet, *Stewart 13451*.

Dryopteris Brunoniana (Wall.) O. Kuntze. Ascent Mir Panzil Pass to the Deosai Plains, 12000 feet, *Stewart 19994*.

Dryopteris Linnaeana C. Chr. Gilgit, *Winterbottom;* near Parkutta, Indus Valley, Baltistan, 8000 feet, *Stewart 20915*.

Dryopteris Levingei (Clarke) C. Chr. Gilgit, Herb. Dehra Dun.

Polystichum Lonchitis (L.) Roth. Gilgit, *Duthie*. Cited by Hope.

Polystichum lachenense (Hk.) Bedd. Gor, Gilgit, 15000 feet, *Tanner*.

Polystichum Prescottianum (Wall.) Moore. Sai, Gilgit, *Tanner;* Parkutta to Tolti, 8000 feet, Baltistan, *Stewart 20928;* Chunagund, Ladak, 9000 feet, *Stewart 21053*.

POLYSTICHUM THOMSONI (Hook.) Bedd. Tarkiti, 8000 feet, Indus Valley and Shyok Valley, Baltistan, *Thomson;* Mir Panzil Pass, 12000 feet, *Stewart 20005.*

ATHYRIUM FILIX-FEMINA (L.) Roth. Ascent Mir Panzil Pass, 12000 feet, *Stewart 19945a.* Approaches var. *retusa* Clarke.

ATHYRIUM RUPICOLA (Hope) C. Chr. Near Bagicha, Indus Valley, 8500 feet, near waterfall, *Stewart 20980* (Det. Morton).

ASPLENIUM VIRIDE Huds. Gilgit, *Tanner, Giles;* Mitsahoi, Ladak Road, 11000 feet, *Stewart.*

ASPLENIUM TRICHOMANES L. Gilgit, 5500 feet, *Tanner;* Satpura Nullah, Baltistan, 10000–11000 feet, *Duthie.* Herb. Dehra Dun.

ASPLENIUM SEPTENTRIONALE (L.) Hoffm. Gilgit, Herb. Dehra Dun.

ASPLENIUM RUTA-MURARIA L. Shingo Valley, Baltistan, 10000–11000 feet, *Duthie;* Kangi Nullah, Ladak, 13500 feet, *Koelz 2828.*

ASPLENIUM FONTANUM (L.) Bernh. Gilgit, *Tanner, Giles;* Baltistan, 10000–11000 feet, *Duthie;* 7600 feet, *Winterbottom.*

ASPLENIUM VARIANS Hook. & Grev. Near Skardu, Baltistan, *Thomson;* near Bagicha, Indus Valley, Baltistan, 8500 feet, *Stewart 21002.*

CRYPTOGRAMMA BRUNONIANA Wall. Ascent Mir Panzil Pass to Deosai, 13000 feet, *Stewart 19986.*

CRYPTOGRAMMA STELLERI (Gmel.) Prantl. Karakorum Mts., 12500 feet, *Clarke;* Chunagund, Ladak, 9500 feet, *Stewart 21059.*

CETERACH OFFICINARUM DC. Gilgit, 8000 feet, *Tanner,* Herb. Dehra Dun.

CHEILANTHES PERSICA (Bory) Mett. Gilgit, 7000 feet, *Tanner;* Skardu. Baltistan, 8000 feet, *Stewart 20428;* Above Kuru, Shyok Valley, *Stewart 20860* and *Kiris 20891.*

CHEILANTHES DALHOUSIAE Hook. Near Bagicha, Baltistan, 8500 feet, *Stewart 20961, 21003.*

ADIANTUM CAPILLUS-VENERIS L. Kangi Nullah, Ladak, 12500 feet, *Koelz 2821;* Kuru to Kiris, Shyok Valley, 8000 feet, *Stewart.*

PTERIDIUM AQUILINUM (L.) Kuhn. Gilgit, *Giles.* Herb. Dehra Dun.

POLYPODIUM CLATHRATUM Clarke. *Duthie,* Herb. Dehra Dun.

EQUISETACEAE

EQUISETUM ARVENSE L. Khalotse to Lamayuru, Ladak, 9500 feet, *Stewart 438a;* Shimsa Kharbu, Ladak, *De Terra* and *Hutchinson,* Herb. New York; Dras Valley, *Osmaston,* Herb. Dehra Dun.

EQUISETUM RAMOSISSIMUM Desf. Common in Baltistan and Ladak.

LYCOPODIACEAE

LYCOPODIUM SELAGO L. Gilgit, 12000 feet; Burzil Pass, near Deosai, *Koelz 9410.*

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